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VOICE IN MAN AND IN ANIMALS.[1]

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II.

IN all languages there exist sounds—vowel and consonant—represented by the letters of the alphabet. This, in the opinion of some linguists, is an evidence of a common origin, while naturalists hold it to be the inevitable effect of the functions of an organ whose conformation scarcely differs in any perceptible degree between one race and another. Nevertheless languages differ very much in the number of their intonations. If, in this respect, the languages of uncivilized nations stand lowest, it does not necessarily follow that the languages of the most highly-civilized peoples must hold the highest rank. The Hindustani is distinguished by an unparalleled abundance of consonants; the Semitic languages surpass the Greek and Latin, as also the languages of modern Europe; the dialects of Polynesia afford instances of the greatest poverty of consonant sounds. Of the Hurons and Mohawks of North America, who habitually kept the mouth open, it is asserted that they knew nothing of the use of the labials—articulations so natural to us that we might be disposed to regard them as instinctive. Sundry nations eschew the use of hissing and trilling sounds;[2] others have no gutturals. Some years ago, preferences for harshness or for softness of language seemed to us to show that neither the vocal organs nor the auditory perceptions are absolutely identical in all races of mankind;[3] this is now rendered more probable by multiplied observations and experiments. We know how great is the difficulty of rendering certain sounds in a foreign language, and hence it is that words change in migrating from place

[1] Translated from the French by J. Fitzgerald, A. M.

[2] *f*, *s*, *z*, *l*, *r*.

[3] "Voyage au pôle sud et dans l'Océanie;" "Anthropologie," par M. Émile Blanchard," 1854.

to place. The Chinese invariably substitute the soft for the hard trill,[1] and this substitution is common among other nations. The Polynesians put gutturals in the place of dentals,[2] and the missionaries who are educating the youth of the Hawaiian Islands have had to abandon sounds that the people are unable to pronounce. It is almost as difficult rightly to hear as it is correctly to imitate articulations foreign to one's own tongue: travelers hardly ever agree in their representations of names that they have heard pronounced by natives. Are differences of voice and of auditory perception the result to a small extent of organization, but to a greater extent of early education? One is tempted to believe that such is the case. But experiment and observation, hitherto very limited, have not yet thrown upon this subject the light of scientific truth.

Words are formed by the combination of vowels and consonants; the voice gives utterance to them; this is language which is at first governed by convention, and then by grammar. Pronunciation results from the emission of articulate sounds; its range in pitch is usually about one-half of an octave. Commonly the voice rises or falls a little at the end of a phrase, producing accent, or marking affirmation or interrogation. The adult man, as a rule, speaks in the lower register, children and women in the upper register, but to this there are many exceptions.

Though we all employ speech, yet we differ in ease and agreeableness of utterance. The voice is weak or powerful, as determined by the mode of action of the respiratory organs. The timbre is sharp, harsh, sweet, or harmonious; this is determined by the conformation of the resonant cavities. Whatever quality of voice we happen to have naturally, is to be preserved, though it may be improved by constant attention to the ear, by steady observation, finally by training. Speech does not flow from its source with the same ease in all cases: here the mind is master, and mental qualities differ from one another to a far greater extent than physical aptitudes. Some persons express themselves without difficulty or hesitation—their thinking faculty acts as a continuous force; others seem to grasp a word or a phrase here and there—their thinking faculty is fluctuating, confused, undecided. A certain feeling of constraint produces stuttering, stammering. It used to be supposed that stuttering is the result of grave defects of the vocal organs, but such is not the case at all; this infirmity has its seat in the mind, and it may be cured or mitigated by systematic effort. It is shown by statistics that Provence, Languedoc, and Guienne, contain a greater proportion of stammerers in their population than any other portions of France.[3] This statement, when

[1] *l* for *r*—*Eulope* for *Europe*.

[2] *gh* for *d*, *k* for *t*. This change of pronunciation is not infrequent in some country districts of France.

[3] "Statistique décennale du bégaiement en France," par Chervin âiné, Lyon, 1866.

first I saw it, was a surprise to me; it has always been thought that no one could possibly falter in his speech who was born near the Garonne.[1]

In performing its great function of establishing all the social relations between man and man, the voice readily calls forth sympathies and antipathies; its quality reveals better than words the true feelings of the heart. A voice that is clear, pure, limpid, conveys the impression of frankness; one that is hesitating, drawling, betokens dissimulation; a harsh, grating voice indicates an evil disposition; while a voice that is sweet, harmonious, affects us as though it were the breathing of a gentle soul. These impressions made by the voice are usually correct, and rightly enough influence the relations of man to man, still we must not trust them too implicitly. No doubt language may serve to disguise thought, but the vocal instrument itself may also produce false impressions. Besides the effects of Nature, we have the effects of art. An orator wishing to make himself heard, or to produce a sensation, opens his mouth widely, and derives from the resonant cavities all the aid that they can supply; this is the declamatory style, condensed by good taste. If the mouth be opened very widely, and the breath emitted with force, the voice becomes imperious: such is the tone in which a military officer gives the word of command. Words that are in themselves simple enough, when uttered in a hard, brusque tone, become offensive. When the sounds are uttered softly, with some degree of tremulousness, the words succeeding one another with deliberate slowness and imperceptible lowering of pitch, the sympathy of the hearer is awakened. Some women, it is asserted, possess a wonderful power of thus rendering their entreaties irresistible. Historians affirm that Cicero's graceful utterance added greatly to the persuasive force of his words. The orator who possesses a good voice, and who can at will assume the tones that best agree with the sentiments, emotions, and passions, which he would arouse, will win the hearts of his auditors, whereas the grandest oration delivered by an unpractised speaker would fail to move them.

Singing requires of the vocal organs functions very different from those required for speaking. Furthermore, a good physical constitution and perfect regularity in the functions of the organism, are of inestimable value to the artist. In the emission of the voice the respiratory movements must be performed without strain or effort; they must be so regulated as to make the inspiration short and easy, and the expiration slow and prolonged. There is a struggle between the organs which retain the breath and those which expel it; practice, youth, and good health, are the conditions upon which an adjustment must be based. In the highly-gifted artist the larynx holds its ordinary position notwithstanding the variations of intensity and pitch of

[1] Memory and the faculty of coördinating words depend upon the brain. It appears, from Broca's researches, that these faculties are destroyed by a lesion of the third frontal convolution of the left side.

the sounds produced. Being implicated in some of the more energetic movements of the tongue, it rises or falls, but to no purpose. The larynx of the singer, while fixed in its position, multiplies its performance; the suppleness of all its parts is a matter of prime importance. The vibrations of the vocal lips and the resonance of the vestibule determine the timbre of the glottic sounds; the configuration of the pharynx and of the buccal cavity, by modifying the sounds formed in the glottis, produces the timbre of the voice. This cannot be altered to any considerable degree by even the most powerful efforts of the will. Professors of singing injure their pupils by prescribing in too absolute a manner the mouth arrangements which they themselves find most serviceable. Each individual must follow Nature, and M. Mandl had good reasons for begging singing-masters never to forget this truth.

Our ear is not affected by all sounds; those which are very low or very acute are not perceived. The limits of hearing are usually set at forty, and at forty thousand vibrations per second. Persons of extreme sensibility are not restricted within these limits, but their gift is not a source of pleasure; every one knows how painful it is to hear sounds that are too acute. Song is the result of modulated sounds separated from one another by harmonic intervals. The whole series of sounds from the grave to the acute is the musical scale; the voice has a greater or less range in different individuals. In the language of musicians, each series of consecutive and homogeneous sounds is a register; we have the chest-register, the head-register, etc. A strange idea has gone abroad: singers, being led astray by the resonance of the arch of the palate, and by certain peculiar sensations caused by the action of various muscles, have supposed that the voice comes now from the chest, again from the head. But, as every one must now be aware, voice is produced always in the glottis. Hence it were well, as M. Mandl advises, to abandon the use of terms which had their origin in a misapprehension, and to use instead of them the terms *lower* and *upper register*.

Singing requires far more precise arrangements of the vocal organs than does speaking. At the moment of producing the sound the glottic orifice should be absolutely shut; the voice-emission will be good provided the vocal lips go apart to the proper extent with a kind of suddenness. It is interesting to follow with the eye, by means of the laryngoscope, the play of the instrument in producing successively low and high notes. In producing very low notes the glottic orifice assumes the form of a very long, regular ellipsoid, with both extremities pointed; as the sound rises in pitch, the vocal lips at once approach each other, and the orifice, constricted at one point, appears to be divided into two parts; the pitch still rising, the uttermost limit of the register is attained, and then the glottic orifice becomes a linear slit. Passing to the upper register—the head-voice or falsetto—a

curious change takes place suddenly in the configuration of the glottis: it appears to be absolutely shut below and open above. In proportion as the orifice is narrowed, the sound grows higher. The singer recognizes the registers by the ear from the timbre, the physiologist by the eye; for the latter, one of the registers consists of the series of sounds produced by the glottis when open along its entire length, the other register represents the series of sounds given forth by the glottis open through only a limited portion of its orifice.

The ordinary limits of the voice include about two octaves of the musical scale; by practice one can easily attain $2\frac{1}{2}$ octaves, but a compass of three octaves, and especially of $3\frac{1}{2}$ octaves, is very exceptional. Hence, at the beginning of the present century, Catalani was regarded as a sort of prodigy. In classing voices according to pitch we recognize three kinds of voice in men, viz., bass, barytone, and tenor, and three in women, contralto, mezzo-soprano, and soprano. Bass voices rarely fall below 173 vibrations, and soprano seldom exceed 2,069 vibrations per second. Still there have been deep voices which produced the note corresponding to 87 vibrations, and acute voices which attained as many as 2,784. The most famous cantatrices of our day are instances of this.[1] The different types of voice are characterized no less by their timbre than by their range. Voices present so many varieties, they are so *personal*, that thorough classification is almost impossible. Endless shades of difference are produced by the degree of intensity of the harmonics: if the intensity is great, the voice is brilliant, mordant; if feeble, the voice is soft, sombre. In the larynx itself, and in the trachea, there occurs a resonance, the effects of which have not yet been determined. In bass voices they are very noteworthy. The famous Lablache would have been an excellent subject for experiments by physiologists.

Having ascertained all the functions of the vocal apparatus, and accounted for the origin of the sounds of speech and singing, we may well be proud of the advance made by science, yet we cannot but be chagrined to think that it is not in our power to determine to what peculiarities of organic conformation the different kinds of voice are to be attributed. All that we can affirm with certainty is, that the sound produced is acute in proportion to the shortness of the vocal cords. One might be inclined to believe that the larynx is more voluminous in bassi than in tenori, in contralti than in soprani; but this is not universally the case. We cannot determine either the compass or the quality of a voice from seeing the instrument. The elasticity, suppleness, and contractility of the tissues, must have an immense in-

[1] In general the bass voice extends from $fa_1 = 173$ vibrations to $re_3 = 580$ vibrations; the barytone from $la_1 = 217$ vibrations to $fa_3 = 690$; the tenor from $re_3 = 290$ vibrations to $si_3 = 976$; the contralto from $sol_3 = 387$ to $fa_4 = 1{,}381$; the mezzo-soprano from $si_2 = 488$ to $la_4 = 1{,}740$; the soprano from $ut_3 = 517$ to $ut_6 = 2{,}069$ vibrations.

fluence on the glottic sounds, and we possess no means of measuring these qualities.

The character of the voice is fixed from the time when the larynx has reached its full development. So long as the activity of youth continues, the voice will retain this character without any very considerable modification; still, by exercise it will perhaps gain intensity, and may be improved in point of timbre. Suppleness and agility of the organs are acquired only at the cost of labor; this is shown from the history of many a singer. The voice of the young Marie Garcia was at first harsh and husky, but afterward it became the sweet voice of Malibran. Still, as a rule, natural physical gifts manifest themselves prior to any attempt at culture.

As old age approaches, the play of the larynx becomes difficult; at first the tone of the voice is lowered, and then its intensity is lessened; the breath comes with less force. Sometimes disease impairs the instrument before the advent of age. While appearing to be intact, the organ often ceases to discharge its functions perfectly, owing to more or less serious affection of the nervous action. Mandl has, by means of electricity, momentarily restored voices that had been thus destroyed. Songstresses have now and then irretrievably lost their voices in consequence of overstrain of the vocal organs. Here we are reminded of the case of Cornelia Falcon.

Amid the refinements of civilized life, singing is prized only in so far as it is an art; when it rises to that dignity, it attracts crowds. A man or a woman possessing no matter how fine a voice, must begin by going to school. The instrument, whose admirable mechanism we have seen, is not entirely under control, except after much study and long-continued and methodical exercise. This is true of all organs subject to the will, as every one knows from experience, as in the employment of the hands. Though expert in all the movements of the larynx and the mouth, the singer cannot, even with a superb voice, produce brilliant effects, save by the aid of mind. From mind alone come expression, taste, style, and these qualities are all personal. Sensibility, whether real or feigned, is always an element of success. The artist is advised never to give way to the passions which he expresses, for mental commotion is quickly succeeded by extreme fatigue; he may attain a perfect imitation of passions, meanwhile preserving a tranquil mind. Still, are not emotions which are felt always the most communicable?

After we have studied the human voice in its various manifestations, the voice of animals seems to us to be scarcely worthy of notice. The barking of the dog, the mewing of the cat, the bleating of the sheep, undoubtedly constitute a very scanty language. These cries of animals do but annoy us; but it must be remembered that they are intended for other ears than ours. The warbling of small birds alone affords us pleasure; it possesses resemblances which cause pleasing illusions; it

seems to express feelings common to ourselves, and hence we like it. The interest attaching to a comparison of the vocal apparatus of animals with that of man has long been appreciated, and the hope has been entertained of being able to explain the nature of all kinds of voice by studying the structure of the organs. Toward the end of the last century, Vicq d'Azyr attacked this problem. Having collected larynges of a number of animals, he regarded them with a sort of enthusiasm; he expected to get from them a revelation. "It is a fine spectacle," said he, "to see at a glance the structure of those infinitely-diversified instruments with which each animal produces its own proper modulations, thus contributing to Nature's grand concert."

The anatomical characters of the vocal apparatus are now pretty well known as regards most of the mammalia. The larynx of these animals is formed upon the same plan as that of man; in monkeys, the resemblance is extreme. The impossibility of speaking is due, as we have reason to suppose, to the conformation of the buccal cavity, the lips, and the tongue. The studies of naturalists, which as yet have not been directed to this point, do not warrant any positive statement: nevertheless, the power possessed by some species of pronouncing one or two syllables justifies a presumption. Does not this vestige of speech indicate the very limited extent of a faculty, not even a trace of which is found in most animals. In 1715 the great Leibnitz announced to our Academy the existence in Meissen of a talking dog, "a peasant's dog, of the most ordinary appearance, and of medium size." This extraordinary animal had learned, says the narrator, some thirty words; these it would repeat after its master. The historian of the Académie des Sciences declares that he would not have ventured to state such a fact "without such an authority as M. Leibnitz, an eye-witness." But, despite so high an authority, the story is a fable. Of the most intelligent dog we still must say, "All he lacks is speech." Were it not that Nature raises an obstacle, surely monkeys that live in the company of man would make the attempt to speak. We must conclude that their intelligence does not incline them toward this sort of imitation, and that their organs are not adapted for articulation.

It is a curious and very interesting fact that, before receiving instruction of any kind, young deaf-mutes who live together quickly discover means of understanding each other, so that they hardly ever misinterpret the feelings and wants expressed by the gesticulations, touches, and facial-muscle action, agreed upon. This instance of a convention between individuals not possessed of the power of employing language of necessity carries our thoughts to the actions of certain animals. The mammalia have a voice that is susceptible of inflexions and intonations more or less diversified according to the species; these they employ in making known to each other their appetites, their wants, to call one another, to announce to one another their

presence. It is often said that animals possess only cries, but this statement is too general. The cat says *miau*, which is a very plain articulation of a labial consonant and three vowels; the word is well formed, and one might suppose it to be Chinese. The cat pronounces this word in many different ways, each having a meaning. If he wants company, he announces his presence in a strong voice; if he wants to be fed, or to have a door opened, his voice is soft and gentle; here is the accent of entreaty. If there is any delay, the tone grows higher, showing impatience. There is a slow, weak *miau*, which the French translate into "Comme je m'ennuie!" ("*How weary I am!*") and again there is the wheedling *miau*, full of pretty modulations, showing plainly a wish to please. Further, the cat says very distinctly *ronron*, a genuine word formed of trills and nasals; here the tongue and the soft palate perform movements which we know from our own experience. This *ronron* now means "Thank you;" again, it expresses joy. When moved by a feeling of dislike for an individual of his own race, or of jealousy of a rival, the animal spits and growls, thus giving utterance to threats and imprecations.

The number of mammals which can articulate syllables is small. Sheep utter no sound but that monotonous *ba*. Some gibbons of the island of Java, when they wish to inspire fear, cry out with fury *ra ra*. For most animals guttural sounds appear to be uttered with greatest ease. The dog, though highly gifted as regards memory, the sentiment of affection, and intelligence, has no language, but only cries; he barks. Short, sudden expirations of air through the glottis produce this well-known voice; yelping is only a modified form of barking, expressive of joy. Howling is the result of a lengthy expiration with great resonance in the pharynx; it expresses profound grief or pain. Dogs express their wants more frequently by movements of the body, by the play of the physiognomy, and by touching with the muzzle than by the voice. They appear to communicate admirably with one another when organizing an expedition; they inform one another of the presence of objects that gratify their appetite. We once saw in the midst of a meadow, far from any house, the flayed carcass of an ox, which had lain for several days absolutely abandoned. A lonely dog, drawn no doubt by the scent, came to get a meal, and went back to the village to tell his acquaintance of what he had discovered; in less than an hour the carcass was torn in pieces by the teeth of a great troop of dogs.

Opportunities of studying the language of animals in the state of freedom are unfrequent; all animals flee from man, and very wisely. In captivity, and cut off from their own kind, they become silent, or merely utter a few cries or murmurs. Were a human being to be held as a prisoner in a family of chimpanzees he would be reduced to the same extremity. Travelers have sometimes observed monkeys when well within range of sight and hearing; they have always ob-

served that the different explosions of voice have each its own meaning, whenever it is designed to establish concert of action between individuals. The cercopitheci, the most graceful and sprightly monkeys of Africa, live together in more or less numerous groups. Having for their usual dwelling-places the branches of trees, they descend to the ground with great misgiving, and only in order to go foraging. On an expedition the band of cercopitheci march under the command of a chief, who is always an old male experienced in the ways of men and animals. At first the troop advance cautiously, passing along the highest branches of the trees. Now and then the chief climbs into one of the loftiest tree-tops and peers into space. If all is well, he makes announcement accordingly in guttural tones, and the troop show that they are reassured; if the chief suspects or perceives danger, he utters a peculiar cry, which is understood by all, and the troop retreat in confusion. The marauders, having reached the edge of the forest, descend to the ground. Then begins a hideous massacre of sorgho and maize. The sajous, those pretty little South American monkeys kept in every menagerie, also show the resources of the inarticulate voice as a means of communication among animals. One day the naturalist Rengger, while wandering along the border of a forest, observed a family of these monkeys whose conduct interested him. One individual, having parted company with the rest, had found an orange-tree loaded with ripe fruit. Without going to the trouble of turning about, he uttered a series of short cries, and made for the tree with the speed of an arrow. The others understood all, and in an instant were assembled amid the branches of the tree, enjoying the savory fruit. If man had no articulate speech, he would have no difficulty in constructing a language by the aid of sounds or cries diversified by intonation, intensity, and resonance, and variously combined. Such a language no doubt could never equal the languages of Homer, of Dante, of Shakespeare, and of Bossuet, but it would answer all the essential needs of life. By supposing such an imaginary though realizable mode of communication, we may form an idea of the more or less limited language of animals.

In mammals the sounds of the voice differ considerably with respect to volume, timbre, and pitch; these differences we can in some measure account for by peculiarities in the conformation of the larynx. In horned animals the vocal cords are lax, but little prominent, never coming near to one another, nor vibrating with much force. The sounds they produce are grave, as in the lowing of cattle. The rodents, as hares, rabbits, squirrels, and mice, whose vocal cords are thin, emit acute cries. Some species, belonging to different mammalian groups, have air-pouches opening into the larynx which produce extraordinary resonance. Some monkeys are distinguished for the enormous development of these pouches, and their voice is very loud. The howling monkeys, also called stentors, which inhabit the deepest

forest recesses of the New World, can be heard, says Humboldt, at the distance of a kilometre and a half, and farther still according to other travelers. In the elephant the lateral cartilages of the larynx do not come into mutual contact, and the vocal cords, having an oblique direction, seem to be incapable of great tension; hence the voice of the elephant is deep, but at the same time very powerful. If we could observe in animals the play of the larynx during the emission of the voice, we should discover many curious and instructive actions of the glottis. But here we meet with an almost insuperable difficulty, for we can place but little reliance on the good-will of animals. Nevertheless, Mandl, trusting to his skill in the use of the laryngoscope, by no means despairs of success, knowing well that by dint of patience we often succeed in removing the most formidable obstacles. After man, birds hold the most prominent place among animate things in the concert of Nature; they enliven field, forest, and garden, with an infinity of chirrupings, leading one's thoughts to dwell on the pleasure of living. The structure and mechanism of the vocal apparatus of birds have been studied by many naturalists. George Cuvier discovered the precise point where the voice is formed. Birds have two larynges, one at the top of the trachea, and the other at the bottom. It is the latter alone which produces the sounds: the former acts only as a resonator. This is easily shown by experiment: if we cut the trachea in the middle, the voice remains. The vocal organ has the form of a box, to which anatomists give the name of drum. It is formed of the lowermost rings of the trachea and the uppermost rings of the bronchi. Commonly the larynx is divided in its inferior portion, sometimes by the angle of union of the bronchial tubes, again by a bony plate which serves as a point of attachment for a membrane rising from the inner margin of each of these tubes, and bounding the glottis with an opposing prominence, the edge of which is elastic. Thus two lips discharge the functions of vocal cords; they become tense or relaxed by the action of a muscular apparatus which in some cases is very simple, in others highly complex. The enormous variety which obtains in the vocal powers of birds necessitates a corresponding diversity in the details of the structure of the larynx and in the conformation of the trachea.

Parrots, being social in their nature, live in large flocks in the most favored climates of the globe; their habit of prattling is not impaired by captivity. When several individuals are together, they appear sometimes to engage in interminable conversations. On the alert for every voice-sound, and even for every noise, parrots imitate these with wonderful ease; thus they readily imitate the articulate speech of man, a phenomenon as yet unexplained. The movements of the tongue, no doubt, play an important part in the articulation of these sounds, but the nature of the resonances leads us to suspect a special activity of the superior larynx. The researches which have

been undertaken into this matter will perhaps throw some light upon one of the most singular aptitudes possessed by animals. It is commonly supposed that parrots cannot attach any meaning to the phrases which they have learned; but this is not strictly exact. Occasionally individuals possessed of the advantages of great natural intelligence and good training employ words to make requests; they make proper reply to a question or to a sign. It might be supposed that parrots owe their power of speaking to the peculiar conformation of their tongue; but this is rendered doubtful by the performances of the magpie, the blackbird, and the starling. In these birds the tongue is thin, and yet they have no difficulty in pronouncing any articulate sound; this fact gives strength to the idea of the influence of the superior larynx. A starling, distinguished for its power of speaking, which at one time we had occasion to observe, very well knew the value of sundry words. He gave expression to his wants in good French, emphasizing his words with the flapping of his wings. This bird was very fond of the bath, and often called for water; on seeing a person taking hold of a pitcher the bird would exclaim, "Come quick, come quick!" with increasing force in case he was obliged to wait.

Most small birds have their call, their chirp of joy or of fright, their battle-cries: all these voice-explosions, containing as they do both vowel and consonant sounds, show how easy and natural articulation is to these animals. The species which possess the power of singing have a very complex vocal apparatus. The nightingale excels all the other songsters of the woods in power, clearness, and sweetness of tone. Her notes, whether joyous or plaintive, are always melodious. This bird acquires the power of song only after long practice. The young ones are usually very indifferent singers, and it is only those individuals which possess special gifts that give to the vocal art its highest expression. Among all the pretty feathered denizens of our woods, the males alone possess a fine voice; they utter their song in order to win mates who cannot compete in vocal talent. They are mute for a great part of the year, but, when the mating season approaches, their nervous action is quickened, and the blood is determined to the organs of voice.

WHAT ARE BATS?

By St. GEORGE MIVART, F.R.S.

THE group of animals called "Bats" is one full of interest to those specially occupied with the study of animal structure—the anatomist, the physiologist, and the philosophical zoölogist. At the same time it must be confessed that bats are far from exciting that general interest which in fact they merit. This disregard, however, is very

natural. The small size of the bats inhabiting this and other parts of the temperate regions of the globe conspires with their nocturnal habits to remove them from general observation, while the great similarity one to another of their different species is an obstacle to their popularity even among zoölogists—since it makes their discrimination and classification a matter of difficulty.

Yet bats are, as I hope we shall see, really *very* interesting animals. The bat exhibits to us the body of a beast, specially modified to live the life of a bird, and at the same time serves to give us a fair conception of certain ancient reptilian forms, the remains of which are found deeply buried in deposits made untold ages ago—in the secondary rocks.

But what is a bat? Probably not one of my readers would be likely, if called upon to answer, to fall into the old error of considering it a kind of bird!

All who have ever examined a bat closely, and observed its fur, ears, and teeth, must, I think, have recognized it as a kind of beast. Its real affinities, however, serve excellently well to demonstrate how little mere external aspect can be trusted as a guide to fundamental relationship. The *bat* is essentially an animal of the air—all its structure is modified for flight, and it rarely *descends* to the surface of the ground. The *mole*, on the contrary, is essentially an animal of the earth—all its structure is modified for burrowing, and it rarely *ascends* to the surface of the ground. The contrast could hardly be more complete, and yet the bat and the mole are cousins—the mole, the hedgehog, and the shrew-mouse, belonging to a group of beasts with which the bats show no inconsiderable affinity.

I have spoken of the opinion that the bat is a kind of bird. This view seems to have been entertained by the Jews, and the "bird of darkness" is placed, in Deuteronomy xiv. 18, among the unclean ones forbidden as food:

"And the stork and the heron after her kind, and the lapwing and the bat."

Aristotle, though he placed the bats among flying animals, and therefore among birds, distinctly recognized the differences in their organization; and the same thing may be affirmed of Pliny. But in spite of this, and although Albertus Magnus, in the middle ages, was fully acquainted with the true nature of bats, as beasts, as well as with their winter torpidity, we find later on a retrogression of opinion.

Thus Belon, in 1557, in his "Histoire de la Nature des Oyseaux," includes bats with his birds. At the same time, he was not unacquainted with the mode of their reproduction.

Yet later—by nearly a century—in 1645, Aldrovandus decided that bats were rather birds than beasts, and this in spite of his careful study of them, as proved by his beginning to distinguish their different kinds one from another.

Some twenty-five years later, Ray gave them their true position among quadrupeds—a position which they have ever since retained.

The Teutonic mind seems early to have appreciated the true nature of bats, as we may judge from the German name, *Fledermaus* and the old English term, *flittermouse*.

Let us look a little closely at our subject of to-day—the bat.

In the first place, there is a little rounded body, covered with soft fur, which is indeed, what Shakespeare calls it, "wool," when giving the ingredients of the caldron of *Macbeth's* witches.

There is a small head, little eyes, large ears, a tail, and two pairs of limbs of very unequal size. The hind-pair (the legs) are of moderate length and singularly disposed, so that the knees are turned almost backward, like our elbows.

Each leg terminates in a foot, furnished with five toes, each with a long, curved claw, all of about the same length. These toes are not webbed, like those of a duck, but are free.

The other pair of limbs (the arms and hands) are of exceeding length. Both the arm and forearm are long—especially the latter—but it is the fingers which are so wonderfully drawn out, and they *are* webbed, like the toes of a water-fowl. Moreover, the web not only connects these long fingers together, but also connects them with the sides of the body and with the legs (as far as the ankle); and does not stop even here, but continues on to the tail, thus connecting it with the two legs.

This large web or membranous expansion has two names. The part belonging to the hand and joining the sides of the body (which is supported by the fingers as an umbrella by its rods) is termed the *alar membrane*. The part connecting the legs with the tail is called the *interfemoral membrane*.

Looking more closely, however, we find that, though the four fingers of each hand are thus bound together, the thumb is free, standing out at a wide angle, and furnished with a very long and strong hooked claw. Of the four fingers, it is only the first which is clawed.

The uses made by the bat of its singularly-formed limbs are, of course, in exact correspondence with their structure. The fore-limbs are true organs of flight; the hind-limbs and tail have a rudder-like action. Besides flight (their predominant mode of motion), bats can crawl upon the surface of the earth with an awkward, shuffling gait. When so crawling, the wings are closed (the long fingers then lying side by side), and the animal rests on its wrists and hind-feet, the body being dragged forward by the help of the strong, hooked thumb-nails, which also help it to climb with ease up any rough surface, even though perpendicular.

When at rest, bats usually hang suspended, head downward, by the claws of their feet, though occasionally they turn round and hang from the claws of their thumbs.

Most nocturnal beasts have large eyes, but most bats have very small ones.

This is perhaps due to the fact that bats in their flight are guided by an extraordinarily delicate sense of touch—so delicate as to seem almost like a sixth sense.

The external ear of most bats appears at first to be double—a very small one seeming to stand up inside the larger one. This appear-

FIG. 1.—HEAD OF LARGE-EARED BAT. *t*, Tragus.

ance, however, is due merely to the very large development of a little piece which in ourselves projects backward as a small rounded process guarding externally the opening of our ear, and called the *tragus*.

The food of our English bats consists of insects, and their teeth bristle with sharp points, well suited to pierce the chitinous cases by which the bodies of insects are protected.

The stomach (like that of most beasts which live upon a purely animal diet) is a simple, short, and rounded bag.

The female is provided with a pair of milk-glands, situated on the breast—as in the apes and in man.

The skeleton of the bat, when compared with those of some other animals, affords an excellent example of how fundamental uniformity of structure may underlie forms which are strikingly different—in accordance with diverging habits of life.

I have already called attention to the divergent aspects of the aërial bat and the subterranean mole. Yet the bones of the flying-organ of the bat closely resemble those of the burrowing organ of the mole, save as regards the relative shapes and dimensions of the component bones. But, while in the bat these bones are drawn out into excessive length and tenuity, in the mole they exhibit the maximum of concentration and robustness. Now, both these conditions are but diverging manifestations of the human structure, and the same indeed may be said of such extreme modifications as the fore-leg of the horse or the paddle of the whale.

But the bat and the mole present us with a special point of similarity in their skeleton not found in the other animals named, including ourselves.

It is that the breastbone in both the bat and mole develops a median ridge or keel. This keel serves to afford additional surface for the attachment of powerful muscles which pass thence to the arms,

and which, in the bat, by their contraction, strike the wings downward in flight.

Every one present must have observed, when carving a fowl, that there is a ridge or keel to the breastbone, and that a voluminous mass of muscle—the breast of the fowl—is situated on each side of such

FIG. 2.—*c*, wrist-bones; *p*, bones of thumb; m_{1-4}, bones of middle part of hands.

keel. Now, our bat has not got such a mass of muscle on each side of the keel of its breastbone as has the bird, and for a very good reason. In the bat, as in ourselves, the muscles which antagonize those just noticed (and which draw the arms away from the breast) are situated in the back; but, in the bird, both the muscles which strike the wings downward, and those which raise them upward, are together placed upon the breast, and hence its much deeper and more conspicuous keel. Still, though the muscular structure of the breast of a bat is not so perfectly arranged for flight as is that of a bird, it is an approximation to bird-structure, and one we can well understand from the similarity of action. But it may puzzle some of my hearers at first to think why the mole, of all creatures in the world, should have a breastbone at all like that of a bird. But a moment's reflection will make it obvious that the mole also requires most powerful breast-muscles, in order that it may dig its way through the soil with the wonderful speed with which it does dig through it. Similar causes produce similar effects, and thus it is that the mole, like the bat and the bird, comes to have a keeled breastbone.

The membrane of the bat's wing is a structure of extreme and peculiar delicacy as regards the sense of touch, and the perfection of this sense is doubtless contributed to by a special condition of its blood-vessels. Although the sense of touch depends, of course, directly on the nerves, the functional activity of the nerves depends upon the quantity and the sufficiently rapid renewal of the blood sent to them. This is shown by the familiar examples of numbness brought about by checking the supply of blood to any part with a ligature, as also by the increased sensibility occasioned by inflammation; that is, through a more copious supply of blood. Now, in most animals, as in ourselves, the heart pulsates with rhythmical contractility; but the blood-vessels which distribute the blood over the body are not themselves contractile, however highly elastic they may be. In the bat's wing, however, the vessels which convey blood toward the heart (i. e., the veins) have been found by Dr. Wharton Jones to be themselves positively contractile, and so fitted in a most exceptional manner to help on the blood-supply, thus indirectly augmenting the power of touch.

This exceptional condition of the vascular system may, then, have something to do with that exceptional perfection of the power of sensation before referred to, and which was experimentally demonstrated by Spallanzani. He found, not having the fear of anti-vivisectionists before his eyes, that bats deprived of sight, and as far as possible also of smell and hearing, were still able not only to avoid ordinary obstacles to their flight in strange localities, but even to pass between threads purposely extended in various directions across the room in which the experiments were made. This skill it is believed is due to an excessively delicate power of sensation possessed by the flying membrane—a power enabling the creatures by atmospheric pressure and vibration to feel, before contact, the nearness of adjacent objects. Dr. Dobson, who has paid more attention to bats, perhaps, than any other living naturalist, is disposed to think, and very reasonably so, that tactile power may be thus greatly increased by such increase of the surface on which tactile sensations may be received as is found in the bat's wing, and that this is the explanation of the mysterious power revealed to us by Spallanzani.

The flight of the bat compared with that of most birds is excessively fluttering; but it is a true and perfect flight, and therefore very different from the analogous action of other beasts called "flying," such as the flying-squirrels, the flying-opossums, and the flying-lemur. In these animals the skin of the flanks can indeed be extended outward to the arm and the leg, and when so stretched (as when these animals take long jumps) seems as a sort of parachute to sustain them somewhat in the air, and so far break their fall as to enable them to flit from one bough to another; but they cannot truly fly. The flying-lemur is the best furnished in this respect, as it has not only a very

extensive "alar membrane," but a short expansion of skin connects together not only the fingers but the toes also (which is not the case in bats), and has a true interfemoral membrane extending from the hind-legs to the tail.

FIG. 3.—A FLYING FROG.

There is no other such instance in beasts, or in any existing reptiles; but web-footedness is carried to such an extreme degree in a certain frog found in Borneo as to give rise to the conjecture that it was a flying animal.

Mr. Wallace, in his travels in the Malay Archipelago, encountered in Borneo a tree-frog (*Rhacophorus*), to which he considered that the term "flying" might be applied. He tells us:

"One of the most curious and interesting creatures which I met with in Borneo was a large tree-frog, which was brought me by one of the Chinese workmen. He assured me that he had seen it come down in a slanting direction from a high tree as if it flew. On examining it I found the toes very long and fully webbed to their extremity, so that, when expanded, they offered a surface much larger than the body. The fore-legs were also bordered by a membrane, and the body was capable of considerable inflation. The back and limbs were of a very deep, shining, green color, the under surface of the inner toes yellow, while the webs were black rayed with yellow. The body was about four inches long, while the webs of each hind-foot, when fully expanded, covered a surface of four square inches, and the webs of all the feet together about twelve square inches. As the extremities of the toes have dilated disks for adhesion, showing the creat-

ure to be a true tree-frog, it is difficult to imagine that this immense membrane of the toes can be for the purpose of swimming only, and the account of the Chinaman that it flew down from the tree becomes more credible."

Although no existing reptile is thus furnished, there is a small Asiatic lizard which is ordinarily spoken of as "flying," the *Draco volans*. And, in fact, though this creature cannot truly fly, but only flit, it has a membrane which can be extended from each side of the body, and which, like the bat's wing, is supported by a number of bony rods. These rods, however, are not, as in the bat, enormously elongated fingers, but are elongated ribs, which stand out freely from the body when jumping, but otherwise are folded back against the flanks.

Existing reptiles, then, present us with no close resemblance to bat-structure; but when we come to extinct reptiles—reptiles which flourished during and anterior to the deposition of our chalk-cliffs—the secondary or mesozoic period—we there find reptiles to have existed which present the most striking analogies with existing bats in all that regards their modes of locomotion, and their structure as far as it is related to such modes of locomotion.

These reptiles flew in the same way that bats do, by means of a vast membrane extending from each enormously-elongated hand to the adjacent side of the body.

While, however, in the bat all the fingers of each hand are enormously elongated (to support the alar membrane)—the thumb alone remaining free—in these flying reptiles only a single finger of each hand was thus elongated, the others remaining short, and being provided with claws like the thumb.

With the approach of the winter season bats (like dormice) fall into a peculiar state of winter sleep called hibernation. For this purpose they generally assemble together in large numbers, in out-of-the-way places, caverns, hollow trees, or the roofs of buildings, hanging head downward by the claws of their feet. During this condition the most important functions of life—breathing and the circulation of the blood—are performed only with exceedingly-reduced activity, the temperature of the body becoming notably diminished.

Some of our English bats may be kept in confinement and partly domesticated for a time, small pieces of raw meat being given to them in lieu of their natural insect-food. Speaking of the long-eared bat, Mr. Bell tells us:

"It is more readily tamed than any other, and may soon be brought to exhibit a considerable degree of familiarity with those who feed and caress it. I have frequently watched them when in confinement, and have observed them to be bold and familiar even from the first. They are very cleanly; not only cleaning themselves after feeding, and at other times, with great assiduity, but occasionally assisting each other in this office. They are very playful, too, and their gambols are not the less amusing from their awkwardness. They run over

and against each other, pretending to bite, but never harming their companions of the same species; though I have seen them exhibit a sad spirit of persecution to an unfortunate Barbastelle which was placed in the same cage with them. They may be readily brought to eat from the hand, and my friend Mr. James Sowerby had one which, when at liberty in the parlor, would fly to the hand of any of the young people who held up a fly toward it, and, pitching on the hand, take the fly without hesitation. If the insect were held between the lips, the bat would then settle on its young patron's cheek, and take the fly with great gentleness from the mouth; and so far was this familiarity carried that, when either of my young friends made a humming noise with the mouth in imitation of an insect, the bat would search about the lips for the promised dainty."

One of the "young friends" here referred to is now the esteemed secretary at the Botanical Gardens, and he has assured me of the truth of the anecdote.

The cry of the bat is exceedingly shrill, so much so that some persons' ears are quite unable to detect it.

Homer compares the voices of the ghosts to the cries of bats. In the twenty-fourth book of the "Odyssey," 6, he says: "As when bats in a corner of a great cave, when one of them has fallen from off the cluster—so they (the ghosts) went along screaming."

Or, as Pope gives it:

> 'Trembling the spectres glide, and plaintive vent
> Their hollow screams along the deep descent,
> As in the cavern of some rifted den,
> Where flock nocturnal bats, and birds obscene;
> Clustered they hang, till at some sudden shock
> They move, and murmurs run through all the rock.
> So cowering fled the sable heap of ghosts."

Bats bring forth but one or two young ones at a birth—when they are received into the interfemoral membrane as into a cradle—the mother then hanging suspended not by her feet but by her thumbs.

The young are born naked and blind, and are suckled at the breast much as is the human infant.

There are many kinds of bats, though their number is uncertain.

There *are* some fourteen species even in England, and at least three hundred and twenty, arranged in some seventy-nine genera, in the world at large.

One of our English bats, already referred to as "the long-eared bat," does indeed merit its name, since it has relatively the largest ears found in the whole animal kingdom, being about equal to the length of its entire body. They are capable of being folded up, and generally are so folded, during sleep.

Another kind of bat found in England is called the leaf-nosed bat, because in it not the ear but the nose is the seat of extraordinary skin-development—productions of skin curiously folded surrounding and surmounting the external nostrils.

The use of this membrane, according to Dr. Dobson, is to serve as a tactile organ (like the wings); and this is the more probable, seeing that that family of leaf-nosed bats which is represented in England have the smallest eyes, and are devoid of a tragus or inner part of the seemingly double ear before spoken of.

Bats are divisible into two great groups. One of them includes all the insect-eating bats (with or without nose-leaves), more or less

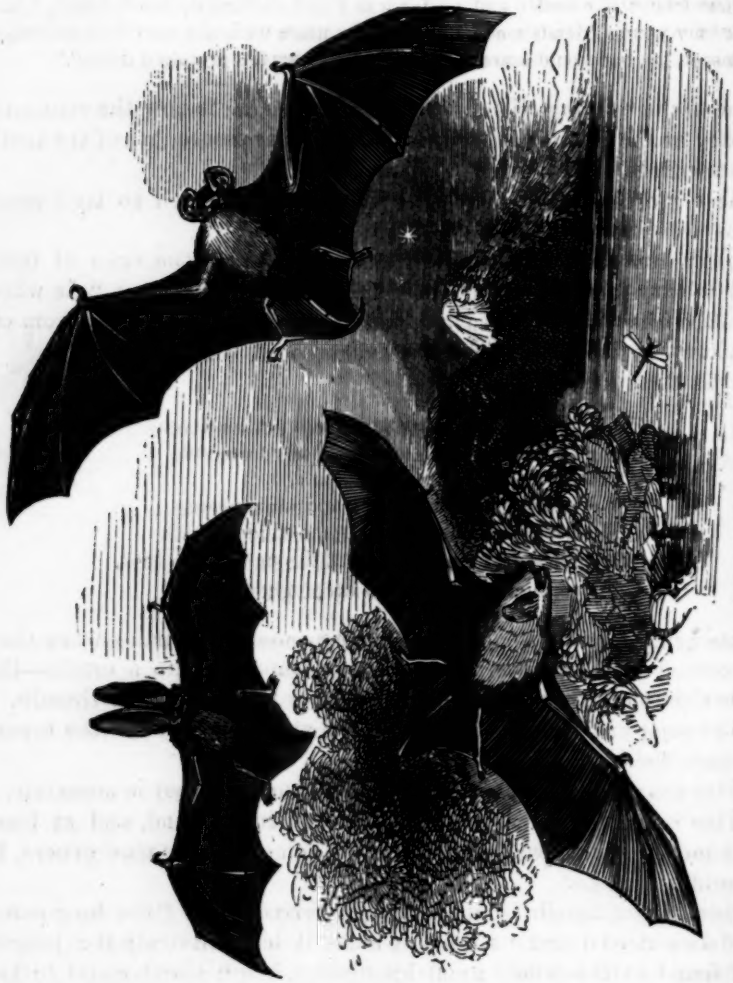


FIG. 4.—BRITISH BATS.

like the bats which inhabit this country. They have almost always teeth such as those already described, often a very large tragus to the ear, and a stomach short and rounded, or at least not prolonged at its pyloric (or more specially digestive) extremity.

These bats are subdivided into various families, three of which alone immediately concern us: 1. The *Vespertilionidæ*, which in-

cludes, among very many others, all the English bats without a nose-leaf; 2. The *Rhinolophidæ*, which includes, among very many others, the English leaf-nosed bats; and 3. The *Phyllostomidæ*, or leaf-nosed bats of America.

The other group of bats are made up of those, mostly of large size, called *flying-foxes*, of which we have specimens now living in the Zoölogical Gardens. They are confined to the tropical and sub-tropical regions of the Old World and the Pacific, but are not found even in the hottest regions of South America. They have grinding teeth, which are not drawn out into sharp points, but have their crowns marked simply with a longitudinal furrow, in accordance with their fruit-eating habits, and their stomach (also in accordance with this habit) is much prolonged at its pyloric, or more specially digestive, end.

Certain leaf-nosed bats of South America go by the formidable name of vampires, from their reputed blood-sucking habits.

Although such a habit could only have been attributed erroneously to the entire group, one certain kind of this group is very truly blood-sucking, and its organization is peculiarly and very strikingly modified to efficiently subserve this function.

The bat in question is called *Desmodus*, and the truth as to its blood-sucking habit has been fully established by the testimony of Mr. Darwin.[1] He tells us: "The vampire-bat is often the cause of much trouble, by biting the horses on their withers. The injury is generally not so much owing to the loss of blood as to the inflammation which the pressure of the saddle afterward produces. The whole circumstance having been lately doubted in England, I was therefore fortunate in being present when one (*Desmodus d'Orbignyi*) was actually caught on a horse's back. We were bivouacking late one

Fig. 5.—Teeth of the Vampire Bat (*Desmodus*). *i*, cutting-teeth; *c*, eye-teeth.

evening near Coquimbo in Chili, when my servant, noticing that one of the horses was very restive, went to see what was the matter, and, fancying he could distinguish something, suddenly put his hand on the beast's withers, and secured the vampire. In the morning the spot where the bite had been inflicted was easily distinguished from being swollen and bloody. The third day afterward we rode the horse, without any ill effects."

The special modifications of structure which harmonize with this

[1] "Journal of Voyage of Beagle," vol. i., p. 22.

special function are mainly two: First, the form of the teeth; and, secondly, that of the stomach.

As to the teeth, the grinding ones are reduced to a minimum both as to size and number; while the two middle or cutting teeth of the upper jaw are of great size, with a sharp cutting edge well fitted to inflict the small incision needful for the animal's nourishment.

As to the stomach, it presents us with a structure unique in the animal kingdom. Here it is not the pyloric end of the stomach, but the opposite or cardiac end, which is produced into an enormously long pouch, while the opposite or pyloric end is reduced to a mere rudiment—the highly-nutritious food (blood) requiring very little digestion, but needing a capacious chamber for its speedy reception.

Although this is the only bat perfectly organized to live by blood-sucking exclusively, nevertheless it is probable that various other kinds practise blood-sucking as at least one part of their mode of nutrition.

The late distinguished zoölogist belonging to the Zoölogical Society, Mr. Blyth, has observed this habit in a leaf-nosed bat of India, one belonging to quite another family than that to which the American vampire belongs. The bat in question is called *Megaderma Lyra*. Respecting its habits Mr. Blyth tells us[1] as follows:

"Chancing one evening to see a rather large bat enter an out-house from which there was no other egress than by the doorway, I was fortunate in being able to procure a light, and thus proceed to the capture of the animal. Upon finding itself pursued, it took three or four turns round the apartment, when down dropped what at the moment I supposed to be its young, and which I deposited in my handkerchief. After a somewhat tedious chase, I then secured the object of my pursuit, which proved to be a fine pregnant female of *Megaderma Lyra*.

"I then looked at the other bat which I had picked up, and, to my surprise, found it to be a small *Vespertilio*, nearly allied to the European *V. pipistrellus*, which is exceedingly abundant, not only here, but apparently throughout India, being the same also, to all appearance, as a small species which my friend Dr. Cantor procured in Chusan. The individnal now referred to was feeble from loss of blood, which it was evident the *Megaderma* had been sucking from a large and still bleeding wound under and behind the ear; and the very obviously suctorial form of the mouth of the vampire was of itself sufficient to hint the strong probability of such being the case. During the very short time that elapsed before I entered the out-house, it did not appear that the depredator had once alighted: but I am satisfied that it sucked the vital current from its victim as it flew, having probably seized it on the wing, and that it was seeking a quiet nook where it might devour the body at leisure. I kept both animals wrapped separately in my handkerchief till the next morning, when, procuring a convenient cage, I first put in the *Megaderma*, and, after observing it some time, I placed the other bat with it. No sooner was the latter perceived than the other fastened on it with the ferocity of a tiger, again seizing it behind the ear, and

[1] In the "Journal of the Asiatic Society of Calcutta," vol. xi., p. 225, quoted in P. Z. S., 1872, p. 718.

made several efforts to fly off with it; but, finding it must needs stay within the precincts of the cage, it soon hung by the hind-legs to one side of its prison, and, after sucking its victim till no more blood was left, commenced devouring it, and soon left nothing but the head and some portions of the limbs. The voidings observed very shortly afterward in its cage resembled clotted blood, which will explain the statement of Stedman and others concerning masses of congealed blood being always observed near a patient who has been attacked by a South African vampire. Such, then, is the mode of subsistence of the *Megaderma*."

Bats are most widely diffused over the surface of the globe, as their powers of flight might lead us to expect. Even Australia—so very peculiar in the character of the other beasts which inhabit it—possesses bats belonging to both of the bat families which are found in our own island.

But, although the whole group of bats, and also that family to which most English bats belong—the *Vespertilionidæ*—are thus widely distributed, the geographical limits of some families of bats are very sharply defined.

To appreciate these facts it is necessary to be acquainted with the geographical areas into which the surface of our globe may be divided, each considerable tract of the earth's surface having its more or less peculiar animal population, or *fauna*, as it has its indigenous plants, that is, its *flora*. The earth's surface is divisible into six zoölogical regions:

1. The *Palæarctic region*, or Europe, Asia north of the Himalayas, and Africa north of the Sahara.

2. The *Ethiopian region*, or Africa south of the Sahara, and including Madagascar and also Arabia, which, geologically, is part of Africa.

3. The *Oriental region*, or Asia south of the Himalayas, with Southern China and the Philippine Islands and Indian Archipelago as far as the island of Bali.

4. The *Australian region*, or Australia, New Zealand, the less remote Pacific Islands, and those of the Indian Archipelago from New Guinea up to Lombok.

5. The *Neotropical region*, or South America, together with tropical North America and the West Indies.

6. The *Nearctic region*, or temperate North America and Greenland.

Now, the whole group of flying-foxes is strictly confined to the tropical regions of the Old World and Australia. In the same way the family of leaf-nosed bats, like those of England—the *Rhinolophidæ*—is limited to the Old World, though reaching there much higher latitudes than do the flying-foxes.

The group to which the vampires belong—the *Phyllostomidæ*—is strictly confined to the Neotropical and Nearctic regions; and the

Neotropical region is not only distinguished as the headquarters of the *Phyllostomidæ*, but also by being altogether destitute of the flying-foxes and *Rhinolophidæ*.

Such being the relation of bats to space—their geographical distribution—what are their relations to time—their geological distribution?

I assume that my readers are acquainted with the fundamental facts and laws of geology, and know that the successive layers, of which the superficial crust of the earth is in very various degrees composed, are classifiable into three sets: 1. The Primary or Palæozoic rocks; 2. The Secondary or Mesozoic rocks (from the Trias to the Chalk inclusively); and, lastly, 3. The Tertiary or Cainozoic rocks, extending upward from the Chalk to the present day.

Fig. 6.—Flying-Fox (*Pteropus Whitmeei*).

Remains of beasts more or less closely resembling some of those existing now in Australia are found low down in the secondary rocks, namely, in the Triassic and Oolitic formations. Generally speaking, however, beasts such as those which now exist are not found deeper than the Tertiary strata, and this is the case with bats.

The oldest fossil bat yet known is represented by a few teeth found in Eocene deposits in Suffolk. The oldest perfect fossil bat is the *Vespertilio Parisiensis* of the gypsum-bed of Montmartre, near Paris.

Some forms of existing beasts, however, which are *now* distinct enough, such as the ox and the pig, or the tapir and the horse, were

preceded in early Tertiary times by others which were more or less intermediate in structure. This is not the case as regards bats. Bats, as soon as they appear at all, appear as thoroughly and as perfectly organized bats as are those living among us now.

This leads us to speculate upon questions of origin; but, before so doing, let us see that we have a clear idea of what a bat is, and can give a good definition of it.

In order that we may have this clear idea, we must consider for a few moments zoölogical classification.

The whole group of animals is fancifully termed the animal kingdom, in contradistinction to the world of plants—the vegetable kingdom.

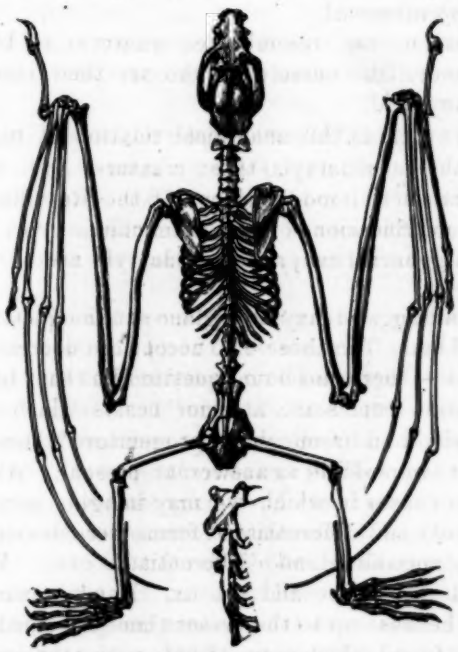


FIG. 7.—SKELETON OF FLYING-FOX. SIDE-VIEW OF STERNUM.

This vast mass of animals is subdivided into a number of very large groups, each of which is a called a sub-kingdom. Thus, we have the sub-kingdom to which we ourselves belong—the vertebrate sub-kingdom; the sub-kingdom of insects, etc.; that of snails, cuttle-fishes, etc., and so on.

Each of these various sub-kingdoms is again divided into certain subordinate, but still very large groups, each of which is called a class.

Thus, the sub-kingdom Vertebrata is made up of the class of man and beasts, that of birds, that of reptiles, that of frogs, toads, and efts, and that of fishes.

Every class is again subdivided into certain subordinate groups, termed orders.

Each order is composed of families, each family of genera, and each genus of its component kinds or "species."

Now, the bat, as already said, belongs to man's own class, possessing as it does all the characters which distinguish that class from the other classes of vertebrate animals.

Man's own class, Mammalia, is divisible into some dozen orders, and all the bats form one such order (*Cheiroptera*), into which no animal but a bat is admitted. The characters of this order are the possession of a truly flying membrane, sustained by very elongated fingers; and the bat is capable of being very shortly defined, namely, as *a truly flying mammal.*

Bats present no real resemblance whatever to birds, but are, of course, much more like ourselves (who are their class-fellows) than they are like any bird.

Similarly, in spite of this analogical relation of bats to those extinct reptiles, the pterodactyls, these creatures have no true affinity. Pterodactyls are aërial modifications of the Reptilian type, just as bats are aërial modifications of the Mammalian type. We may say, in a rough and general way, as pterodactyls are to rèptiles, so are bats to mammals.

Before concluding we may now glance at the question of the genesis or origin of bats. To those who accept the doctrine of Evolution —as I myself do—there can be no question but that bats did arise by natural generation from some anterior beasts which were not bats. But at what period and from what progenitors? these are questions which it is quite impossible to answer at present. As has been said, there are certain cases in which we may imagine now existing more highly specialized and differentiated forms were developed from anterior less highly specialized and differentiated ones. We may do so, e. g., as regards the horse and the ox. But we cannot do so as regards the bat, because up to the present time no fossil remains whatever have been found which connect bats with other creatures. Moreover, the development of the bat's wing, difficult as it is to conceive upon any view of evolution, seems to me to be especially difficult as the mere result of the survival of the fittest, when we consider the origin of the initial stages of the organ. The nearest existing relatives of the bats which are not bats are perhaps the little shrew-mice belonging to the order Insectivora. Some of these are aquatic; and it is conceivable, though there is no fragment of evidence in favor of it, that some ancestral aquatic form may have developed long fingers and webs like those of the flying-frog. This speculation does not, however, commend itself to my mind as a satisfactory one; and though, doubtless, could we see all the extinct forms of life which have existed during the secondary period, we should find some creat-

ures developing by more or less rapid stages along a definite course in the direction of the type of structure selected for our consideration to-day, and, though I am ready to make an act of scientific faith in the existence of such creatures, I confess my imagination fairly baffled in its attempts to depict them, or the road which this particular course of evolution followed. We must wait patiently for more light from paleontology. But we may wait very hopefully. We may do so because the wonderfully rich harvest of fossil remains now being gathered in North America supplies us with good and solid ground for hope.

Already forms have been discovered there so strange that they cannot be satisfactorily grouped in any existing order of mammals—forms such as imagination could hardly have anticipated. We may, then, not unreasonably expect that sooner or later—perhaps very soon—fossils deeply buried in the secondary rocks will come to light, clearly pointing out the line which has been followed in the evolution and development of the only truly flying mammal—the bat.—*Popular Science Review.*

ON THE FORMATION OF LAKES.

By I. C. RUSSELL.

IT was not until the studies of Agassiz, Forbes, and others, among the Alps of Switzerland, had made us acquainted with the character and action of glaciers, that we could at all understand many of the most curious and interesting features connected with the formation of the multitude of lakes with which we are more or less familiar, and which lend so much beauty and grandeur to the scenery of the world.

As some classification is necessary for the understanding of a series of facts, we will arrange lakes under four heads: 1. Those filling glacier-worn rock-basins; 2. Those confined by banks of sand, gravel, bowlders, etc., or, in one word, by moraines; 3. Those formed by a subsidence of their bottoms, or by the elevation of the country surrounding them, commonly by the secular changes of level to which the crust of our globe is subject; 4. Lakes filling basins formed by volcanic action.

1. Lakes which fill rock-basins are such as are confined on all sides by the common rock of the country, so that in some cases a person can walk entirely around them without stepping off the solid rock; and in all cases they would be found to have a rocky rim inclosing them, were the superficial material removed. How such spoon-shaped depressions could be scooped out, was for a long time an enigma which eluded the search of the most painstaking observers.

As facts accumulated, however, it was noticed that the sides and bottoms of such lakes are smoothed, in many cases polished, and almost always covered with grooves and scratches; and also that in their vicinity beds of clay are usually found, intermixed with pebbles and large bowlders which, like the rocky basins, are also smoothed and frequently scratched. It was noticed, too, that the rock from which these bowlders and pebbles had been formed commonly differed from the rocks in place on the shores of the lakes. Thus, throughout New York and Ohio, huge bowlders are common, composed of crystalline rock found in place nowhere nearer than the Canadian Highlands, a hundred miles to the northward; while the peculiar native copper of Northern Michigan is sometimes found mingled with the bowlders and striated stones of the drift far southward in Ohio.

The problem now was to discover what forces in Nature could *polish* and *scratch* both rock-surfaces and detached stones, and could also transport masses of rock, tons in weight, far from their native home.

It is well known that the loose stones and pebbles along the seashore are made very smooth and round, and often polished, by the action of the waves. It might be thought from this that the pebbles found on the shores of the lakes, and imbedded in the clays, were fashioned in the same manner. On one occasion, at the Cape of Good Hope, the writer, after wandering for a time along the sloping sandy beach of Table Bay, came suddenly to a little rocky cove exposed to the full swell of the South Atlantic. As each wave broke on the steep, rocky beach and retreated, it was followed by a sharp, rattling sound that could be distinctly heard above the roar of the waves; we noticed, too, that the stones all along the shore were in motion, rolling down the beach, only to be caught up by the next white-capped wave that came in from the ocean, and again carried up the beach, and rolled and pounded against each other by the untiring waters, that were fast reducing them to sand and dust. On examining these water-worn stones, we found them all smoothed and rounded, and often beautifully polished; but in no case could we discover, even with a magnifying-glass, any that were scratched, or in any way marked similarly to the stones which we have so often examined in the clays and hard-pans that cover so great a portion of our Northern States. From this fact, and also from watching the action of the waves on many other coasts, we conclude that the sea tends to smooth and wear away the stones and rocks along its shores, but has no power to cover them with grooves and scratches; and that, instead of wearing the coast into pockets and basins, it tends only to grind down the islands and continents to one uniform level.

Again, we have traversed the deep, picturesque valleys of the southern Alps, where we could see the glaciers glittering on the mountain-sides far up at the head of the valley, and have noticed as

we advanced that the rocks became more and more worn and rounded; that in sheltered places, along the sides of the valley, beds of thick plastic clay were to be found; and also that the whole valley was strewed with smoothed and rounded pebbles, together with huge bowlders, many of which were a hundred tons in weight. These were often planed off and grooved, precisely like many of the transported stones that are scattered so plentifully over the hills and valleys of the State of New York; and like them, too, frequently differed in the nature of their material from the rocks of the surrounding cliffs. As we ascended the valley, these peculiarities became more and more strongly marked; while around us the hills and knolls had a rounded and flowing outline, and formed what are known as *roches moutonnées*, the mountain-peaks that towered above were sharp and angular, and stood out against the clear sky like cathedral-spires.

All these facts have such a marked and intimate connection with the glaciers that still linger on the mountain-side, that no one—who had traversed those valleys, or traced the streams up to the ice-caves, from which many of them spring, turbid and overloaded with silt, at the foot of the glaciers—could doubt that these valleys, with all their peculiar features, owe their existence to the great extension of the glaciers, which in past time flowed from the mountains in great rivers of ice, and carved out those grand valleys to a depth of many thousands of feet in the solid rock. As these ancient glaciers retreated and melted away, they left the indisputable records of their presence throughout the valley.

The same connection of rounded and striated bowlders (called *Fündlinge*—wandering children—by the German peasants) with existing glaciers has been observed by Agassiz and others in the Alps of Switzerland. Not only these facts, but the manner in which the glaciers flow down the valleys like great rivers of ice, has been closely observed and measured; they have been seen time and again transporting immense amounts of dirt and stones on their surface, which in time formed part of the terminal moraines at their extremity. The sides and bottoms of the valleys through which they flow are smoothed and covered with scratches made by the pebbles and stones set in the bottom and sides of the glacier, which in their turn were rounded and scratched, often in various directions, caused by their breaking from their matrix, and being reset in a new position.

If we were to place the rounded and scratched stones from the drift ("hard-pan," "hog's-backs," etc.) of New York beside the similar stones broken from their icy fastenings in the bottom of the glacier of Zermatt, we should find them so similar in their markings that no eye could distinguish but that they had made the journey under the glacier side by side.

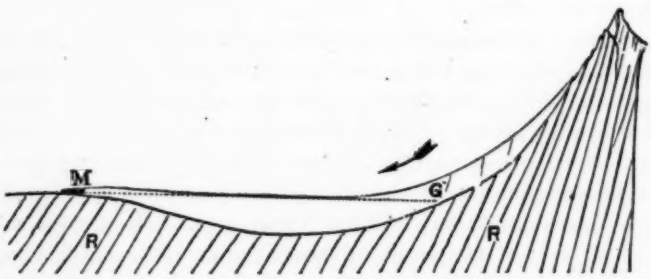
If we compare the smoothed and striated rocks from the bottoms and shores of Lake Erie, Cayuga Lake, or almost any of our lakes

which fill rock-basins, with the rock-surface fresh from under the ice of the Mer de Glace, we shall find them wonderfully similar in their markings. The characters that are engraved upon them are the same.

Not only do we find these markings in connection with the present glaciers, but we find also the rock-basins themselves with the glaciers yet occupying their upper portions, and still at work grinding down the rocks. The best example of this kind, perhaps, in the world, is Lake Wakatipu, in New Zealand, which has a length of seventy miles, and a depth of 1,400 feet. This lake fills a true rock-basin, and bears every indication of having been excavated by the glaciers, which in the past were greatly extended, and have now retreated to the extreme upper end of the valley, while it has no connection with synclinal folds or volcanic fractures.

How can we resist the conclusion, then, that these bowlders, these beds of clay full of smoothed and striated pebbles, and these rock-basins with their sides covered with inscriptions—which we can now read with ease and accuracy if we take the records made by existing glaciers, as the Rosetta Stone—are all the work of glaciers, since the same results are produced at the present day by the action of ice, and by no other agency known?

A clearer idea of the manner in which a flowing glacier wears out a rock-basin can be gathered, perhaps, from the accompanying diagram, where the rock *R R* is shown, over which passes the glacier *G*,



which wears its bottom less at the lower end, not only for the reason that the ice is continually wasting away, and growing thinner in the lower portion, but also because the material carried down on the surface of the glacier is deposited at its extremity *M*, in the form of a terminal moraine, and thus protects the rock beneath from further waste. When the ice of the glacier is melted away, and the terminus retreats up the valley, the basin which it leaves behind it becomes filled with water (from *M* to *G*), and thus forms a lake, which may be a mere pool across which a school-boy can skip a stone, a great inland sea like Lake Erie or Lake Ontario, or a mirror of grandeur like Lake Geneva or Lucerne, in Switzerland, and Lake Wakatipu and Lake Wanaka, in New Zealand.

It may be urged that these beds of clay, with their striated stones and huge bowlders, are found over a large section of our country, and are not confined to the region of the lakes. This is very true; and from it we conclude that where now so many happy homes are scattered, from Maine to the far West, the snows and frozen mists of a great winter once accumulated to many thousand feet in thickness, and formed a great glacier, like that which covers the interior of Greenland at the present day, which flowed southward, grinding down the country and acting as a ploughshare to prepare the land for a new harvest. Gradually this great winter began to pass away, and the spring-time in which we now live, to draw near. As the great glacier retreated northward, it left the country covered with beds of bowlder-clay and strewed with huge erratics from northern regions, which together with other *débris* form the surface material of all our northern country, where it has not since been swept away or covered by other and more recent deposits. It is often well exposed along our lines of railroads, and may be known at a glance by the great number of worn and rounded stones of all sizes that are scattered promiscuously through it. These evidences of glacial action are found as far southward as Cincinnati and the central portion of New Jersey, showing that here was the border of the icy mantle that was spread over all the northern regions. After this great continental glacier passed away, or had retreated far northward, smaller and detached streams of ice still flowed southward to complete the task of moulding the valleys and lake-basins. It is to these smaller glaciers that we attribute the formation of the multitude of lakes filling rock-basins that are scattered through the northern part of the United States and over the whole of the British possessions, many of which have been hollowed out in nearly horizontal beds of rock in the same manner as lake-basins are now forming under existing glaciers. Nor are the lakes which fill glacier-worn rock-basins confined to our own continent, but they form the most common and grandest lakes of temperate latitudes, which might be called the lake latitudes, so completely are the lakes of the world confined to these regions.

The theory of the glacial origin of certain lakes was first proposed by the distinguished English geologist, Prof. Ramsay, and, after being tested in nearly every glaciated region in the world, is now held, by those best qualified to understand it, as the simple and true history of the formation of many of our lakes.

2. The lakes of our second class, those which are confined by banks of gravel, bowlders, etc., owe their origin, like the ones we have been considering, to the action of ice. Lakes of this class are most commonly found in the deep Alpine valleys of mountainous regions, where the material which accumulated on the surface of the glaciers that once flowed through them, in the form of lateral and medial moraines, was carried down and deposited at the extremity of the

glacier in what is known as a terminal moraine, which in many cases stretched completely across the valley and marks the place where the terminal face of the glacier was stationary for a considerable period of time before it melted away, and allowed the water to accumulate in the space once filled by the ice. These glacier-built dams are to be met with in all countries which have been subjected to glacial action, and are especially well marked amid the Alps and in Scotland, where they have been most thoroughly studied, on the Scandinavian peninsula, in the Northern States of the Union, and amid the southern Alps of New Zealand. As the bottom of the valley in which such a lake is formed is usually worn deeper by the action of the glacier during the formation of the terminal moraine, this second form of lake-basin is quite often combined with the first.

To this second class also belong the thousands of little lakelets scattered over the Northern States, which are confined on all sides by banks of drift-material, and fill nearly every depression and hollow in the huge banks of glacier-worn *débris*—known as *till*, *kaims*, *eskers*, etc., scattered so plentifully throughout our Northern country. We have seen many of these pretty little lakelets through New York, Ohio, and westward. Near Plainfield, New Jersey, scores may be passed in a morning's walk. At the latter place they occupy the hollows and dells in the drift, which is there of great thickness, and formed not only from the Triassic sandstone which underlies it, but also to a large extent from the limestone and gneiss found in place only in the northern portion of the State. Intermingled with these are many blocks of the peculiar reddish conglomerate found *in situ* in Morris County, which show unmistakably the direction from which the drift has traveled. Many of these stones are glacier-worn, and have without doubt been transported from their northern homes by the agency of ice; not in one or two isolated instances, but in sufficient quantity to cover the country for miles in extent. These little lakelets, becoming filled with vegetable matter, form peat-bogs, which promise to become of considerable agricultural value in the future; these peat-bogs not only contain many wonderful things for the eyes of those who are fortunate enough to possess a microscope, but also in them are sometimes found the bones of the huge mastodon, which at no very distant time inhabited this continent.

3. The formation of lakes by a sinking of their bottoms, although at first sight seeming to be the simplest and most common mode of their formation, is really the most unusual. Lake Superior is described as filling one of these depressions, as the rocks on its shores are found to dip toward the centre of the lake, and the basin seems to have been formed by a subsidence at that point, although greatly modified in after-time by the erosion of the ice during the glacial period. The valley into which the Jordan empties is another such region of subsidence.

No description has been given of the newly-discovered lakes of Central Africa, sufficiently accurate to decide to which mode of formation they owe their origin, but, as they are situated in the tropics, it will probably be found that, like Lake Superior, they fill synclinal valleys.

To this category belong also the truly great lakes which existed in our Western country during Tertiary times, which in the lapse of ages became filled with mud and silt, and now form the greater portion of the rich Territories of Nebraska, Dakota, etc. In this region are found, in great numbers, the remains of the huge animals which lived in these ancient lakes, and fed on the luxuriant tropical vegetation that overhung their banks.

The well-known Salt Lake of Utah is another example of a lake filling an area of depression, and was of far greater extent in past time, as is very plainly shown by the lines of ancient terraces which are so sharply drawn between Ogden and Salt Lake City, nearly a thousand feet above the present level of the lake.

4. Lakes of the fourth class, such as owe their formation to volcanic action, are found occupying the bowl-shaped craters of ancient volcanoes, which, as their fires became extinct, furnished convenient reservoirs for the accumulation of water, and in this manner sometimes formed lakes of considerable extent. Streams of lava, also, when they chance to flow in such a manner as to obstruct the drainage of a valley, may serve as a dam, above which the waters soon accumulate and form a lake.

Besides the kinds of lakes which we have enumerated, there are others, which are of rare occurrence and exceptional in their mode of formation; such is the beautiful little lake in Switzerland known as the Märjelen-See, which is formed by the glacier of the Aletsch blocking up the mouth of a tributary valley, and thus forming a wall of ice above which the waters accumulate. This ice-dam breaks away every few years, and allows the complete and rapid drainage of the lake, which often causes great inundations of the valley below. In ancient times a similar ice-dam existed in the valley of Glen Roy, Scotland, as has been shown by Lyell, which, by damming back the waters, formed a lake similar to the Märjelen-See. The waves of this ancient glacial lake chafed and wore its banks, and thus formed terraces at different levels, in the same manner as we often see the little ripples on the pools of water by the wayside cut their soft, muddy banks into terraces, so that, when the water is evaporated by the heat of the sun, their sides are left in a series of little steps; in the same manner, but on a far grander scale, the terraces were formed which are known as the Parallel Roads of Glen Roy, that have gained a world-wide fame both in science and story.

In our own country we sometimes find lakes which owe their existence to the industry of the beavers, who often build their dams in our streams, and sometimes form shallow lakes of considerable extent.

The lakes to which we have devoted the greatest attention, and which are at the same time the most common and the most interesting, are those which fill glacier-worn rock-basins, to which we hope that our little article will attract the attention of some one who will give us more light on these wonderful pictures, now but imperfectly illuminated.

AMPHIBIOUS FISHES.[1]

By E. SAUVAGE.

IN the swamps of the Gambia, after they have been dried by the tropical sun, there are to be found here and there beneath the surface clods of earth uniform in shape, and usually about the size of a man's two fists. These clods inclose living animals, which have been led by instinct to hide themselves away toward the close of the rainy season, and before the coming of the season of drought, by burying themselves in the mud while it was yet soft, and before it had been hardened by the scorching rays of the sun.

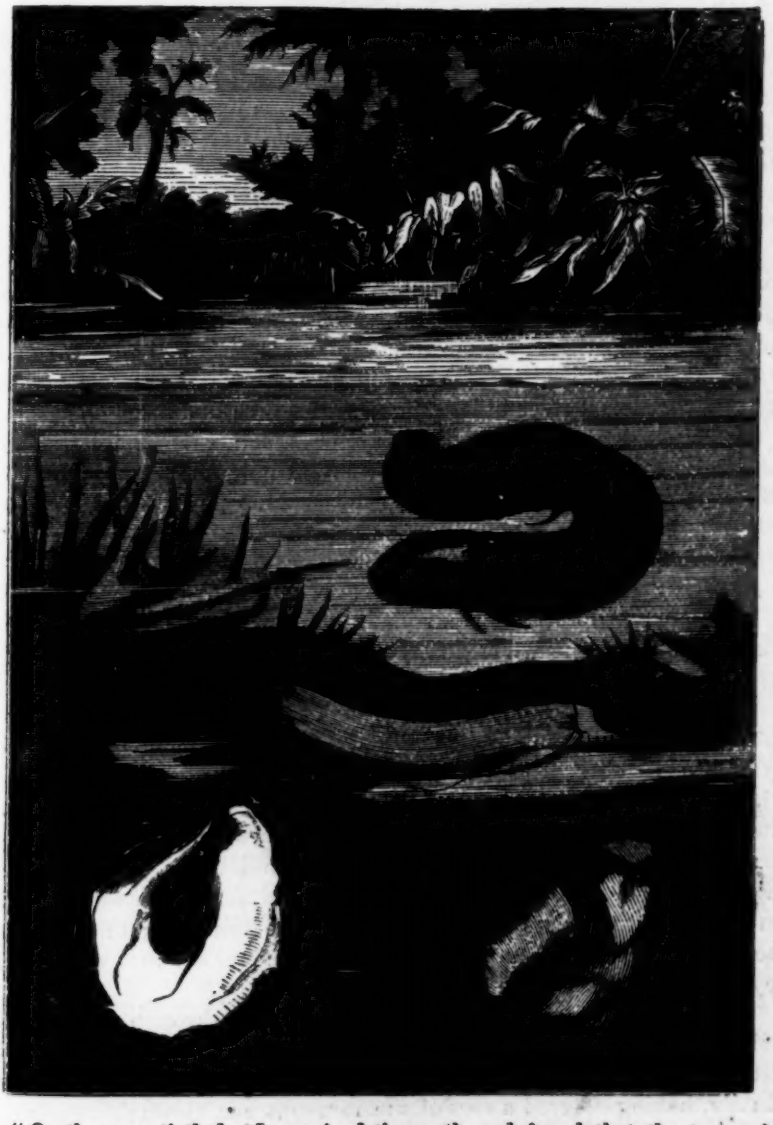
On breaking one of these lumps of mud, it is found to be a sort of pouch or cocoon, with thin walls, and with projections here and there corresponding to the form of the animal concealed within. Its larger end is rounded, but its narrower end is closed by a slightly convex lid with a narrow opening in the centre. If the surface of the cocoon be even gently touched, a pretty loud cry is heard which Natterer has compared to the mewing of a cat.

For a long time it was supposed that the animal buried itself amid the leaves which surround its protecting sheath. In a special memoir published in the Bulletins of the St. Petersburg Academy of Sciences, Leuckart expressed the opinion that the epidermis, by becoming detached, supplied the materials for this envelope. But since his time it has been demonstrated that the cocoon is formed from a dense secretion of mucus; such is the result of observations made by Paulson and Richard Owen, and repeated by Auguste Duméril, Professor of Ichthyology at the Museum. He has himself witnessed the formation of the cocoon, and his description of the process we repeat here in his own words. He says:

"Two protopteri, that had been restored to freedom by the gradual softening of the clods in which they had been inclosed, evinced signs, after living for a month in an aquarium, that the time had come for them to seek, in the soft earth covered by the water, the shelter which they require during the dry season. Their restlessness, their abundant secretion of mucus, their attempts at burrowing, all showed an irresistible desire to find a medium different from that in which they then lived.

[1] Translated from the French, by J. Fitzgerald, A. M.

"I therefore took pains to surround them with conditions analogous to those they meet with when, after the water has retreated, the soil first becomes dry, and then hardens. The water in the aquarium was drawn off little by little as soon as the animals had burrowed into the mud. Three weeks had scarcely passed, and already the hardened earth showed a number of cracks; through these a small quantity of air is admitted, which supports respiration.



"On the seventieth day I examined the earth, and found that the two animals had met with such conditions as enabled them successfully to live through the artificially-produced dry season: they were enveloped in cocoons, and were full of life, as was shown by their motion on being touched ever so lightly.

"Thus the cocoon is a protecting sheath formed of the mucous secretion. The abundant secretion of mucus, in the first place, coats and strengthens the walls of the burrow made by the protopterus, and hence the subterraneous canal which it had excavated had its sides smooth, and as it were polished. Then, after the animal has reached the required depth, the secretion becomes still more abundant, and the mucus dries, forming a membranaceous envelope of remarkable structure."

The animal doubles itself up in its envelope, the tail being brought up in front of the head; the mouth is free, and through it passes the air needed for respiration, which, of course, is exclusively pulmonary, owing to the conditions in which the animal lives. In fact, the protopterus is able to respire in two ways, viz., either directly in the atmosphere, or indirectly by separating dissolved oxygen from water by means of its gills.

The external openings to the latter are two small apertures, one on each side of the neck. Each of these gives access to a chamber of moderate capacity, in which are floating certain filamentous appendages. On these are distributed the blood-vessels, which constitute but ill-developed tufts. In water, the animal respires by means of these; when it lives in its burrow, it respires by means of its lung.

Most fishes have, beneath the vertebral column, a sort of capsule, which seems to act the part of a floating apparatus. By means of this, the fish can rise in the water or descend at pleasure; it is known as the air-bladder. The sounds emitted by certain fishes, *Triglæ*, for example, are caused by vibrations communicated to the gases in this organ.

In the protopterus the air-bladder discharges the physiological functions of a lung when the animal can no longer respire through the gills. To attain this end, it divides up into a number of little cellular lobes, over the walls of which are spread a multitude of blood-vessels, containing blood to be oxygenated, though it is only partially venous. To prevent mixture of the two kinds of blood, that which has respired the oxygen and that which has discharged its physiological function, the auricle becomes divided in two by a partition. The left chamber receives the red blood, just as in the higher animals. A muscular *frænum*, or fold, forming a sort of rudimentary septum, rises from the floor of the ventricle; this *frænum* acts as a piston, preventing the return of the blood into the vessels by contracting when the heart contracts.

The air enters either through the mouth or through the nostrils, which debouch near the posterior margin of the upper lip; thence it passes into a trachea, which traverses the wall of the œsophagus; finally, having entered a sort of membranous sac, through two large openings, it reaches the lungs, whereof there are two, and which are like the lungs of serpents.

These singular animals, being, as we have said, truly amphibious,

have received from naturalists the expressive name of *Dipnoi*, a term formed from two Greek words, meaning animals with twofold respiration.

Two genera, each comprising only one species, make up this subclass *Dipnoi*. Gambia, Zanzibar, Senegal, the region of the White Nile, and the Niger, are the native haunts of the African species, the *Protopterus annectens*, or *anguilliformis;* the other species, *Lepidosiren paradoxa*, is found in the valley of the Amazonas.

The latter species is but ill represented in collections; there are in Europe only a very few specimens. According to Mr. Bates, the natives call it *zambaki mboya;* this naturalist says that the *Lepidosiren* has even penetrated to the great lakes in the vicinity of the Tapajos and the Madeira. M. de Castelnau has caught this animal in a marsh on the left bank of the Amazonas, above Villanova, at a place called Caracauca.

In *Lepidosiren* the tail is pointed; the pectoral and ventral fins, which stand far apart, are not long, and consist of a single ray, not divided into segments. The general form is that of an eel, with two threads hanging on each side. In color the animal is dark brown-gray, or olive, with round spots of lighter color, about the size of the scales, and indistinct on the head and the middle of the back. The species appears to grow to the length of about one metre.

The protopterus, or African representative of the group, is olive-green in color, this tint being varied with a number of irregular brown or blackish spots. The lower portions are violet. The young are marked with fine lines of light color, which cross each other, forming a regular network. The extremity of the tail is tapering. The pectoral and ventral fins are long, and consist of one ray made up of jointed segments. The bones of the skeleton are of a green hue.

For our first acquaintance with these animals we are indebted to the naturalist Natterer, who, during his visit to Brazil, obtained two specimens, which he placed in the Vienna Museum. For a long time the *Protopterus* and *Lepidosiren* were classed with those batrachians in which the tail persists, as in the axolotl. Later they were considered as forming a sort of intermediate class between reptiles and fishes, and as forming the connecting link between the two. At present naturalists class *Lepidosiren* and *Protopterus* among fishes.

The *Dipnoi* are not the only class of animals that bury themselves in the dried-up mud after the water has been evaporated by the heat of summer. There is another fish that does the same—the mud-fish (*Amia*), which is found in the fresh waters of the United States. The *Amia*, too, is indisputably a *fish*. There appears to exist some relation between this animal's mode of life and the cellular structure of its air-bladder. Still, the *Amia* is not an amphibian, in the strict sense of the term. For, though its air-bladder resembles the lung of

the serpent, it certainly receives only blood that has previously been aërated; hence we find in this animal no true aërial respiration alternating with strictly aquatic respiration.

But, though the *Amia* is not amphibious, and hence not to be considered in this place, nevertheless we must not omit to mention the fact that, while at present the genus is restricted within rather narrow geographical limits, it appears to have existed in Europe during the epoch known to geologists as the Middle Tertiary.

Thus there have been found at Oeningen (Switzerland), Kutschlin (Bohemia), Ménat and Armissan (France), fossil remains of *Cyclurus*, which has a close affinity with *Amia*. It is highly probable, not to say certain, that these fishes buried themselves in the mud during the dry season. The little tertiary lakes of Limagne appear to have undergone in past times alternations of drought and humidity, like the marshes of tropical and inter-tropical countries.

The presence in Europe of a genus closely allied to the *Amia* of America would seem to show that, at a relatively late period, these two divisions of the world were connected. The study of tertiary insects, to which E. Oustalet has devoted himself, and a thorough investigation of fossil fishes, would, we think, tend greatly to confirm Oswald Heer's hypothesis, according to which an Atlantis—not an historical Atlantis, as understood by Plato, but a geological Atlantis—connected the north of Europe with America toward the close of the great Tertiary epoch.

INDUSTRIAL APPLICATIONS OF SOLAR HEAT.[1]

By L. SIMONIN.

THE history of burning-mirrors of brass is known. At Rome the sacred fire was lighted with apparatus of this kind, and Archimedes fired the ships which were blockading Syracuse by concentrating upon them the sun's rays by means of a large reflector. Buffon repeated successfully the experiments of Archimedes. With a mirror of very slight curvature, consisting of a number of pieces of looking-glass, he set fire, at some distance, to fir and beech planks, melted tin and silver, and brought iron to a red heat. Saussure later accumulated, by means of superimposed inclosures of glass, the sun's heat up to a temperature exceeding that of boiling water, and Sir John Herschel repeated these experiments at the Cape of Good Hope at various times between 1834 and 1838. At the same period the French physicist Pouillet was engaged at Paris in measuring the calorific intensity of solar radiation, arriving at the conclusion that the heat emitted

[1] Translated from the French, by J. Fitzgerald, A. M.

from the sun and poured down upon the earth in one year would suffice to melt a sheet of ice thirty metres thick, and enveloping the entire globe.

About the year 1860, M. Mouchot, then Professor of Mathematics in the Lycée of Alençon, being stimulated by the researches of Pouillet as well as by those of Melloni, the ablest of Italian physicists, who has made experiments of incomparable precision upon the transmission of heat, boldly attacked the question of the utilization of the sun's heat. The mechanical equivalent of heat had at length been determined. Thanks to Melloni, we already knew the quantity of caloric which different bodies, as glass, when reduced to thin laminæ, suffer to pass through, as also the difference in the reflecting power of polished metallic surfaces according to the nature of the metals, employed. But to measure the amount of *vis viva* transmitted daily from the sun to the earth, and, more Utopian still, to concentrate, at little cost, the sun's rays, so as to realize all the effects of which they are capable, were objects the attainment of which was henceforth insured, though Buffon and Saussure had failed, owing to the insufficiency of the data at their command. The question is now merely a matter of calculation, an application of well-known physical laws.

In order to concentrate to any useful purpose the sun's rays, there was need of a receiver which should be of moderate size and reasonable cost. After sundry attempts, one of which was with an apparatus resembling that of Saussure, Mouchot contrived a vertical boiler of copper, blackened on the outside, covered with three concentric bell-glasses, and resting on some bad conductor of heat, as sand, brick, or wood. Soon he increased the power of his apparatus by the addition of a metallic reflector, which enabled him to dispense with two of the three bell-glasses. With this apparatus he considerably raised the temperature of the water in the boiler, reduced it to vapor, melted sulphur, the liquefaction temperature of which is 116° C., and after twenty minutes of insolation brought the empty boiler up to the temperature of 200° C.

With this reflector a few seconds suffice to set on fire a heap of shavings or a piece of board. In a glass vessel placed at the focus of the reflector and inclosed in another vessel of glass, one kilogramme of tin has been melted in two minutes; the same quantity of lead took five minutes, and of zinc, six. The fusion-point of these three metals is 235°, 335°, and 475° C. respectively. With spherical or parabolic mirrors, whose focus is a point, and not a line, as in the conical or cylindrical mirrors employed in the foregoing experiments, the concentration of solar heat would have been still stronger.

While engaged in these investigations, the ingenious experimenter brought out his *Marmite Solaire*, a cylindrical glass vessel, in which is placed another cylinder of copper or of wrought-iron blackened on the outside, and resting on the bottom of the glass receiver. The

whole is covered with a glass lid. A cylindrical reflector of silver directs the sun's rays upon the apparatus. With this *marmite* it takes less than four hours to prepare an excellent *pot-au-feu*, consisting of one kilogramme of beef and a quantity of vegetables, the whole being perfectly cooked, and very palatable, owing to the fact of the heat being applied with great regularity.

In this form of marmite, now superseded by a simple glass vessel fixed at the focus of a conical mirror of silver-plated brass, fruits, potatoes, all sorts of legumes, meats, and grains, are cooked by solar heat. So, too, an infusion of tea or coffee can be readily prepared, and for this purpose we may employ one of those bottles of colored glass in which Lyons beer is put up. To cook legumes or grains rapidly, a different course may be taken. A closed vessel containing water is set in the focus of the reflector, and, when the liquid begins to boil, the upper portion of the vessel is connected by a tube with the bottom of another containing the legumes or grains, which are quickly cooked by the steam.

To transform the marmite into an oven, a disk of wrought-iron is placed beneath the glass lid, and in less than three hours a kilogramme of bread is baked. The crust is hard and brown, and the pith light and well raised, as with bread baked in an ordinary oven.

The roasting of meat, not requiring the same amount of heat as does the vaporization of an equal weight of water, can be performed in the open air, by the action of the solar reflector alone, the piece of beef, veal, or mutton being fixed upon a spit. In less than an hour we have in this way a very fine roast. The use of butter must be avoided, lest the chemical rays, by transforming the butter into butyric acid, should spoil the flavor of the meat. By interposing a pane of green or red glass we can intercept the chemical rays which cause this fermentation, and then the result leaves nothing to be desired.

By substituting for the two lids of the solar marmite an alembic-head, the apparatus can be used for the purposes of distillation. To this end the alembic-head is connected, by an horizontal tube, with a worm, the latter descending in the form of a helix and dipping into a constant current of cold water, while the metallic vessel, containing two litres of wine, is inclosed in the glass cylinder and set in the focus of the reflector. The alcohol is collected after forty minutes of exposure to the sun. Inasmuch as the apparatus grows hot slowly and continuously, the alcohol is highly concentrated and possesses a very agreeable aroma.

In all the foregoing experiments, M. Mouchot at first used concave silver mirrors, cylindro-parabolic in form, i. e., cylindrical mirrors whose base-line is an open curve resembling a parabola. The reflecting power of cylindrical mirrors increases in proportion to their aperture, and hence the time required, for instance, to boil a litre of water is inversely as the aperture of the mirror, i. e., the greater the aperture

the shorter the time. But later the inventor has employed only conical mirrors, and in these the insolation surface is quadrupled when the diameter of the mirror is doubled.

Mouchot's researches did not end here. He proposed further to obtain mechanical effects with solar heat, and in the beginning of August, 1866, he put in operation at Paris the first machine of this kind.

In the mean time Ericsson was studying these same problems, without knowing anything about Mouchot's experiments. Starting from the facts collected by Herschel and Pouillet, Ericsson, in the first place, estimated the action of the sun upon a surface of nine square metres to be sufficient to vaporize eight litres of water; consequently it would be equal to one horse-power. From these premises he deduces striking consequences, as, for instance, that the solar heat falling on the roofs of Philadelphia alone would suffice to drive 5,000 steam-engines of twenty horse-power each. Then, having demonstrated that upon one square mile, using only one-half of the surface and devoting the remainder to buildings, roads, etc., we can drive 64,800 steam-engines, each of a hundred horse-power, simply by the heat radiating from the sun, he adds these remarkable words: "Archimedes, having completed his calculation of the force of a lever, said that he could move the earth; I affirm that the concentration of the heat radiated by the sun would produce a force capable of stopping the earth in its course." Again: "In England they are beginning to calculate the time when the coal will give out, though coal-mines are, so to speak, of recent exploitation. A few thousands of years—drops in the ocean of time—will exhaust the coal-mines of Europe, unless, meanwhile, recourse is had to the aid of the sun. True, the sun's beams do not every day reach the surface of the earth; but, when the great magazine is opened which shall supply heat gratuitously without cost of transportation, the prudent engineer will know how to provide a reserve against cloudy days. At the same time we would observe that a large proportion of the earth's surface is illumined by an ever-radiant sun. The solar engine's sphere of activity is as great as its dynamic power is considerable." Mr. Ericsson, who, besides genius, possesses wealth and a long experience, will doubtless some day take up again his studies upon the mechanical application of solar heat. Meanwhile, we must state what has been done in this direction by a Frenchman.

The traveler who visits the library of Tours sees in the court-yard in front a strange-looking apparatus. Imagine an immense truncated cone, a mammoth lamp-shade, with its concavity directed skyward. This apparatus is of copper, coated on the inside with a very thin silver-leaf. On the small base of the truncated cone rests a copper cylinder, blackened on the outside, its vertical axis being identical with that of the cone. This cylinder, surrounded as it were by a great

collar, terminates above in a hemispherical cap, so that it looks like an enormous thimble, and is covered with a bell-glass of the same shape.

This curious apparatus is nothing else but a solar receiver, or, in other words, a boiler, in which water is made to boil by the heat-rays of the sun. This steam-generator is designed to raise water to the boiling-point and beyond, by means of the solar rays, which are thrown upon the cylinder by the silvered inner surface of the conical reflector. The boiler receives water up to two-thirds of its capacity through a feed-pipe. A glass tube and a steam-gauge communicating with the inside of the generator, and attached to the outside of the reflector, indicate both the level of the water and the pressure of the steam. Finally, there is a safety-valve to let off the steam when the pressure is greater than is desired. Thus the engine offers all desirable safety, and may be provided with all the accessories of a steam-boiler.

The reflector, which is the main portion of the generator, has a diameter of 2.60 metres at its large, and one metre at its small base, and is eighty centimetres in height, giving four square metres of reflecting surface, or of insolation. The interior walls are lined with burnished silver, because that metal is the best reflector of the heat-rays; still brass with a light coating of silver would also serve the purpose. The inclination of the walls of the apparatus to its axis measures 45°. Even the ancients were aware that this is the best form for this kind of metallic mirrors with linear focus, inasmuch as the incident rays parallel to the axis are reflected perpendicularly to the same, and thus give a focus of maximum intensity.

The boiler is of copper, which of all the common metals is the best conductor of heat; it is blackened on the outside, because black possesses the property of absorbing all the heat-rays, just as white reflects them; and it is inclosed in a glass envelope, glass being the most diathermanous of all bodies—that is to say, the most permeable by the rays of luminous heat. Glass further possesses the property of resisting the exit of these same rays after they have been transformed into dark rays on the blackened surface of the boiler. None of these applications of physical laws present any novelty; people reduced them to practice instinctively, as it were, before men of science could assign the reasons. Here the arts of cookery and of gardening, and the processes for warming our rooms, did not wait for the experiments of the physicist. Saussure himself started from these data in his researches; but the inventor needed the discoveries of modern physics in order to give to these applications a rigorous formula.

The boiler proper of the Tours solar engine consists of two concentric bells of copper, the larger one, which alone is visible, having the same height as the mirror, i. e., eighty centimetres, and the smaller or inner one fifty centimetres; their respective diameters are twenty-eight and twenty-two centimetres. The thickness of the metal is only three millimetres. The feed-water lies between the two enve-

lopes, forming an annular envelope three centimetres in thickness. Thus the volume of liquid is twenty litres, and the steam-chamber has a capacity of ten litres. The inner envelope is empty. Into it pass the steam-pipe and the feed-pipe of the boiler. To the steam-pipe are attached the gauge and the safety-valve. The bell-glass covering the boiler is eighty-five centimetres high, forty centimetres in diameter, and five millimetres in thickness. There is everywhere a space of five centimetres between its walls and those of the boiler, and this space is filled with a layer of very hot air.

The earth, owing to its diurnal and annual revolution, does not occupy the same position with regard to the sun at all hours of the day, or in all seasons of the year. This being the case, the generator is so contrived as to revolve 15°, or one twenty-fourth of its circumference, hourly around an axis parallel to the earth's axis, i. e., so as to follow the apparent diurnal motion of the sun, and to incline gradually on this axis in proportion to the solar declination. Hence the intensity of the utilized heat is always nearly the same, whatever the hour of the day or the season of the year, inasmuch as the apparatus is always so arranged as to reflect with the least possible loss all the rays emitted by the sun. This double motion of the generator is effected by a very simple contrivance.

The generator just described is the one which M. Mouchot was enabled three years and a half ago to set up at Tours, the Conseil Général of Indre-et-Loire having provided the funds. It has yielded curious results, some of which are worthy of being recorded here, though before long they will be surpassed, when some improvements have been made in the apparatus. On May 8, 1875, the weather being fine, twenty litres of water at 20° C. temperature was introduced into the boiler at 8.30 A. M., and took only forty minutes to produce steam with a pressure of two atmospheres; in other words, a temperature of 121° C. was obtained, which is 21 centigrade degrees above boiling-point. This steam then quickly acquired a pressure of five atmospheres. This was the safety limit of the strength of the apparatus: if the process had been carried any further the boiler would have exploded. Toward noon on the same day, with fifteen litres of water in the boiler, steam at 100° C., i. e., a pressure of one atmosphere, was raised in less than fifteen minutes to five atmospheres—a temperature of 153° C. Finally, on July 22d, about one hour after mid-day, the heat being exceptionally great, the apparatus reduced to vapor five litres of water per hour, which is equal to one hundred and forty litres of steam per minute, or half a horse-power.[1]

[1] A maker of instruments of precision, J. Salleron, who constructed the solar apparatus which was presented to the Institut last year, lately wrote to me as follows: "I have driven a small model steam-engine, with the steam generated in the boiler of this new generator, and M. Noel, Professor of Physics in the Vendôme Lycée, put the same engine in operation on January 5th last. The water began to boil after twenty-eight minutes, the hour being noon, and the temperature of the surrounding air near 0° C."

A steam-engine consists of two principal parts, the boiler and the engine proper, or motor. We suppose that with the boiler employed at Tours we can use the common motors; this is one of the advantages possessed by the solar apparatus, viz., that it does not require a special form of motor. At first the inventor employed for his demonstrations a double-acting engine, without either condensation or detention of steam, the cylinder of which had a capacity of one-third of a litre. This engine performed eighty strokes per minute, with a steady pressure of one atmosphere; it continued to work even under a slightly-clouded sun. This was later superseded by a rotary engine, that is, an engine with revolving cylinder, which avoids all transmission of movement; but the system is faulty. Yet this engine worked very well, driving at high velocity a little pump for raising water; the pump, however, being of weak construction, became disabled. It is a pity that the inventor has never measured the real work performed by his engine, by means of a dynamometer.

The solar reflector, being first of all a furnace using fuel that costs nothing, is not only of use as a means of developing motive force, but can also be employed for a multitude of purposes—for instance, distilling water to make it fit for drinking, concentrating and crystallizing saline solutions, preparing alcohol, etc. Five litres of wine can be distilled in a quarter of an hour by passing the vapor from the apparatus into a still. The manufacture of alcohol from grain, sugar-cane, or beet-root, would be equally easy. The steam generated by this apparatus can also be employed for cooking fodder for cattle. M. Mouchot has devised a form of small marmites, quite different from his large steam-generator. These can be used by hunters for preparing their meals, and explorers of great deserts will now have something besides camel or buffalo chips for cooking their victuals.

Many and varied are the uses of this curious invention. The aëronaut can with its aid propel his air-ship. Hot-air motors and ammonia engines will be benefited by the use of the solar receiver; but it is especially in tropical countries that it is destined to find immediate employment, in driving the various kinds of machinery used in sugar and cotton plantations, in distilling impure water to make it fit for drinking, in crystallizing saline and saccharine solutions, in pumping water of irrigation, in manufacturing ice by means of the Carré machine, etc. In those countries fuel is scarce, firewood is not abundant, and coal, which has to be imported from a distance, often from the mines of England, commands an exorbitant price. Already in southern countries sea-salt is obtained purely by the action of solar heat. In Chili and in Mauritius, salt-marshes are divided into compartments, with walls and roof of glass, in order to promote evaporation; so in the famous nitre-beds of Iquique, on the coast of Peru, the salt might be crystallized by solar heat alone.

The cost of a solar apparatus of half a horse-power, like that

at Tours, does not exceed fifteen hundred francs, and, when the manufacture is carried on upon a large scale, will be much less. By substituting for the silver plate, which is the most costly portion of the reflector, brass with a thin coat of silver, which will serve the purpose equally well, a considerable reduction of cost is effected.

As the insolation surface, and consequently the power of the apparatus, is quadrupled when the diameter of the mirror is doubled, it will be easy to construct large generators without adding very much to the cost or complicating the mechanism. The one thing to be avoided in this case will be too great intensity of heat. It cannot be objected that the conical reflector takes up too much room, for a common steam-engine occupies considerable space likewise with its long boilers and its high chimney; as for the motor, properly so called, and the contrivances for transmitting the power, they are the same in both cases.

The strongest winds, at least in our latitudes, have no action on the reflection of the solar heat, or upon the mirror itself, which is not shaken by them. This is an important point, for this is an apparatus which must always be exposed in the open air. In regions where the wind-storms are more severe than they are here, the reflector might be staid and strengthened with iron ribs, so as to resist the most violent cyclones. It has been demonstrated that the bell-glass, even when highly heated by the direct radiation from the boiler, is in no danger of breaking, even when a cold rain falls upon it, and that it is even proof against hailstones; and now that a process has been invented for tempering glass and making it almost unbreakable, we can without difficulty obtain bell-glasses strong enough for any emergency.

Experience will hereafter lead to many improvements now unthought of; but even as it stands to-day the solar engine at Tours is ready to pass from the speculations of theory to the application of practice. It is neither over-costly, nor difficult to set up, nor so complicated as to require great skill in managing it; and, from whatever point of view we regard it, it meets and overcomes all objections. We may say that it lends itself to every industrial use in which solar heat can be employed, especially in tropical countries where the absence of all kinds of fuel for industrial uses is severely felt. In the not distant future, in other countries, too, there will exist no other fuel than the sun, no other engines than those driven by solar heat. By that time no doubt the means of storing up this heat will have been discovered, for in our latitudes we shall have to make provision against cloudy days and seasons of rain, which unfortunately constitute the major part of the year.

It may appear to be a pleasant paradox to say that future generations, after the coal-mines have been exhausted, will have recourse to the sun for the heat and energy needed in manufacture and in domestic

economy. Still, nothing could be plainer than this. In our day, when it is probable that force, motion, gravity, heat, light, electricity, magnetism, are simply modifications of one and the same agent, and the effect of the vibrations of that impalpable and invisible fluid known as ether, the assertion that the sun is the only fuel, the only force, must not call forth anywhere the smile of incredulity. All fuels, all forces, are to be regarded as only parts of the sun's heat. What is coal? Fossil carbon. And was not this carbon fixed in plants by the sun's heat, of which it is the equivalent? Under the action of solar radiations the carbonic acid in the atmosphere is decomposed on contact with plants; the carbon is fixed in the plant, and the oxygen goes back into the air to serve for the respiration of animals. Hence, no sun, no vegetation; no vegetation, no carbon; no carbon, no coal. Coal, in burning, gives up the solar heat which was stored up in it, and therefore it was that, on seeing a locomotive engine move, Stephenson said: "It is not the coal that drives this engine, it is the sun's heat stored up in the coal thousands of ages ago; locomotives are but the horses of the sun." We might make a like comparison with respect to wine and the alcohol it contains; and the Bordelais use no mere figure of speech when they speak of their admirable Sauterne wine as being "bottled sunshine."

When water rises in the shape of vapor, what is it that causes it to ascend? The heat of the sun. If it comes down as rain, forming torrents and brooks which feed our mill-races and drive our mills, what is it that turns the wheel? The sun, for it was the sun that in the first place raised the water. When the wind blows upon the sails of a windmill, or on the sails of a ship, what is it that drives the mill or propels the ship? The sun, for wind is simply an atmospheric current produced by the heating of a stratum of air which, being dilated by the sun, tends to an equilibrium with strata of the same density, and hence rises, while a volume of cooler air takes its place. And what are the tides, the propulsive power of which there is some thought of utilizing, whether directly by means of water-wheels, or indirectly by compressing air and so producing a constant supply of force? They are a portion of the heat of the sun, for the seas are formed by the coming together of all those torrents and rivers which descend into their common reservoir, the ocean. Then, too, the tides are the result of the combined attraction of sun and moon upon the earth. Thus we find that the sun is always and everywhere active.

It is, therefore, no paradox to regard the sun as the one source of fuel in the future, and as the reservoir of force to which generations to come will at no distant day have recourse. Hence it is that *savants* and great engineers, as Euclid, Archimedes, Hero, Salomon de Caus, Buffon, Saussure, Bélidor, Evans, Herschel, Pouillet, Ericsson, have in every age put to themselves the question how it might be possible to take from the sun a part of its heat for the benefit of this poor globe.

The world will not perish for want of coal, yet the coal-supply will fail, and that much sooner than Ericsson estimated, for the production doubles every ten or fifteen years. It will not take thousands of years to exhaust the European coal-mines, but only hundreds, and not very many hundreds either. In England, as appears from recent calculations, the supply will have been consumed in two or three centuries at the farthest. Belgium, Germany, France, and the other countries of Europe, are no better off. The United States of America and the north of China have coal enough to last for one thousand years, and that is all. We must then have recourse to the sun.

It will perhaps be said, "There is electricity." Electricity, as a mechanical agent, is too costly; to produce electricity we have to consume copper, zinc, and acids. Now, one kilogramme of copper, zinc, or acid represents several kilogrammes of coal expended in procuring it. In reducing copper-ore according to the Welch method, sixteen kilogrammes of coal is consumed for each kilogramme of copper obtained. Hence it were reasoning in a vicious circle to suppose that electrical or electro-magnetic machines can usefully or economically take the place of steam-engines. There is only one case in which this conclusion would be weakened; namely, if with a thermo-electric pile we should succeed in decomposing water into its elements, oxygen and hydrogen, at little or no expense. The problem would then be solved, for this would place in the hands of all the two greatest sources of light, heat, and force—oxygen and hydrogen. But, even then, to what should we owe this unexpected solution? To the sun, for it is only by the aid of a thermo-electric pile (wherein we suppose electricity to be produced by solar heat) that we could economically decompose oxygen and hydrogen; else it would require at least as much heat to dissociate them as they would yield on recombining—a *petitio principii* overlooked by those simple inventors who persist in attempting, by means of ordinary electric piles, to solve the great problem of economical motors and the fuel of the future.

As for directly storing up solar heat in good conductors or absorbents of heat which are then to be insulated—for instance, receiving the heat in porous black stones which are first exposed to the sun and afterward thrown into a great reservoir, just as snow is piled up in the ice-house—it involves no impossibility. These stones could be thrown into water, if needs were, and in this way we might easily attain or surpass the temperature of boiling water.

Straw, sawdust, wool, feathers, confined air, are insulating substances which retain heat. We might surround with a double envelope of this kind the reservoir holding the sun-heated stones, and in this way we might have our store of solar heat, as now we have our store of ice. It is one problem whether we have to retain cold or to retain heat. Now, ice keeps very well even when stowed in the hold of a vessel; a little sawdust and careful stowage do the whole work.

The same means will serve in storing solar heat, and, if need be, shipping it to a distance. We have barely outlined the idea, but certain we are that at the proper time the scientific man will appear who shall discover a practical method of doing this.

The sun, as it would appear, will be the fuel of the future, and one might say that this was foreseen by the great encyclopædic scholar of the middle ages, Dante, when in his incomparable poem he said, "*Guarda il calor del sol che si fa vino*"—"Look at the sun's heat which changes into wine"—as though he meant to say, into all that is force, all that is life, all that is light.—*Revue des Deux Mondes.*

THE REVIVED THEORY OF PHLOGISTON.

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IN 1781–'83, Cavendish showed that when inflammable air or hydrogen, and dephlogisticated air or oxygen, are exploded together in certain proportions, "almost the whole of the inflammable and dephlogisticated air is converted into pure water," or, as he elsewhere expresses it, "is turned into water."

On June 24, 1783, the experiment of Cavendish was repeated on a larger scale and in a somewhat different form by Lavoisier, who not only confirmed the synthesis of the English chemist, but drew from it the conclusion—at first strongly contested, then rapidly acknowledged, and since never called into question—"that water consists of inflammable air united to dephlogisticated air," or that it is a compound of hydrogen and oxygen.

This conclusion, so opposite to his own preconception on the matter, Lavoisier subsequently confirmed by an analysis of water. He found that iron, heated to redness and exposed to the action of water-vapor, became changed, by an abstraction of oxygen from the water, into the self-same oxide of iron procurable by burning the metal in oxygen gas—the other constituent of the water, namely, its hydrogen, being freely liberated.

With the demonstration by Lavoisier of the composition of water began the triumph of that antiphlogistic theory which he had conceived, in a necessarily imperfect form, so far back as 1772, or before the discovery of oxygen, and had brought to completion by the aid of every successive step in pneumatic chemistry, achieved by himself or by others.

In 1785, the relationship to one another of hydrogen and water being then conclusively established, Berthollet declared himself a convert to the new theory of combustion put forward by his countryman.

Fourcroy next gave in his adhesion; and soon afterward De Morveau, invited to Paris expressly to be reasoned with by Lavoisier, succumbed to the reasons set before him. The four chemists then associated themselves together, and, in spite of a strong though short-lived opposition both in England and Germany, succeeded in obtaining for *La Chimie Française* an all but universal recognition.

The principal articles of the new or antiphlogistic theory of combustion propounded by Lavoisier are as follows: That combustible bodies in burning yield products of various kinds, solid in the case of phosphorus and the metals, liquid in the case of hydrogen, gaseous in the case of carbon and sulphur. That in every case the weight of the products formed by the burning is greater than the weight of the combustible burned. That the increase of weight is due to an addition of matter furnished to the combustible by the air in which its burning takes place. That bodies of which the weights are made up of the weights of two or more distinct kinds of matter are of necessity compound; whereas bodies of which the weights cannot be shown to be made up of the weights of two or more distinct kinds of matter are in effect simple or elementary. That, inasmuch as the weights of the products furnished by the burning of different combustibles are made up of the weights of the combustible burned and of the oxygen consumed in the burning, these products are compound bodies—oxides in fact of the substances burned. That, inasmuch as given weights of many combustibles, as of hydrogen, sulphur, phosphorus, carbon, and the metals, are not apparently made up of the weights of two or more distinct kinds of matter, these particular combustibles are in effect elementary; as for the same reason is the oxygen with which in the act of burning they enter into combination. And, lastly, that combustion or burning consists in nothing else than in the union of combustible matter, simple or compound, with the empyreal matter, oxygen —the act of union being somehow attended by an evolution of light and heat. And, except that it would be necessary nowadays to explain how, in certain cases of combustion, the combustible enters into union not with oxygen, but with some analogue of oxygen, the above precise statement might equally well have been made by Lavoisier in 1785, or be made by one of ourselves at the present day.

Lavoisier's theory of combustion being known as the antiphlogistic theory, the question arises, What was the phlogistic theory to which it was opposed, and which it succeeded so completely in displacing? This phlogistic theory was founded and elaborated at the close of the seventeenth century by two German physicians, Beecher and Stahl. Having exercised a scarcely-disputed authority over men's minds until the notorious defection in 1785, it preserved for some years longer a resolute though tortuous existence, and was to the last defended and approved by our own Priestley and Cavendish—who died, the former in 1804, and the latter in 1810.

The importance attached to the refutation of this theory may be judged of from the circumstance that, after the early experiments of Lavoisier on the composition and decomposition of water had been successfully repeated by a committee of the French Academy in 1790, a congratulatory meeting was held in Paris, at which Madame Lavoisier, attired as a priestess, burned on an altar Stahl's celebrated "Fundamenta Chemiæ Dogmaticæ et Experimentalis," solemn music playing a requiem the while. And the sort of estimation in which the Stahlian doctrines have since been held by chemists is fairly illustrated by a criticism of Sir J. Herschel, who, speaking of the phlogistic theory of chemistry, says that it "impeded the progress of the science, as far as a science of experiment can be impeded by a false theory, ... by involving the subject in a mist of visionary and hypothetical causes in place of the true acting principles." Possibly, however, this much-abused theory may yet prove to contain an element of permanent vitality and truth; anyhow the study of this earliest and most enduring of chemical theories can never be wholly devoid of interest to chemists.

To appreciate the merit of the phlogistic theory it is necessary to bear in mind the period of its announcement. Its originator, Beccher, was born in 1625, and died a middle-aged but worn-out man in 1682, a few years before the publication of the "Principia." His more fortunate disciple, Stahl, who was born in 1660, and died in 1734, in his seventy-fifth year, though afforded a possibility of knowing, seems equally with Beccher to have remained throughout his long career indifferent to the Newtonian principle that the weight of a body is proportionate to its quantity of matter—that loss of weight implies of necessity abstraction of matter, and increase of weight addition of matter. Whether or not the founders of the phlogistic theory conceived that change of matter in the way of kind might, equally with its change in point of quantity, be associated with an alteration in weight—and it must not be forgotten what pains Newton thought it necessary to take in order to show the contrary—certain it is, they attached very little importance to the changes of weight manifested by bodies undergoing the metamorphosis of combustion. It might be that when combustible charcoal was burned the weight of incombustible residue was less than the original weight of charcoal—it might be that when combustible lead was burned the weight of incombustible residue was greater than the original weight of metal—this was far too trifling an unlikeness to stand in the way of the paramount likeness presented by the two bodies. For the lead and charcoal had the common property of manifesting the wonderful energy of fire; they could alike suffer a loss of light and heat—that is, of phlogiston—by the deprivation of which they were alike changed into greater or less weights of inert incombustible residue.

And not only were these primitive students of the philosophy of

combustion unconscious of the fact and meaning of the relationship in weight subsisting between the consuming and the consumed body, but they were altogether ignorant of the part played by the air in the phenomena which they so boldly and successfully attempted to explain. Torricelli's invention of the barometer, and Guericke's invention of the air-pump, were both, indeed, made during Beccher's early boyhood; but years had to elapse before the consequent idea of the materiality of air could be domiciled, as it were, in human understandings. And not until more than a century after Torricelli's discovery of the weight of air—not, indeed, until the time of the great pneumatic chemists, Black, Cavendish, Priestley, and Scheele—was it ever imagined that the aërial state, like the solid or liquid state, was a state common to many distinct kinds of matter; and that the weight or substance of a rigid solid might be largely contributed to by the weight or substance of some constituent having its independent existence in the aërial or gaseous form. The notion that 100 pounds of smithy-scales might consist of 73 pounds of iron and 27 pounds of a particular kind of air, and that 100 pounds of marble might consist of 56 pounds of lime and 44 pounds of another kind of air, was a notion utterly foreign to the older philosophy. Air, it was allowed, might be rendered mephitic by one kind of contamination, and sulphurous by another, and inflammable by a third; it might even be absorbed in, and so add to the weight of, a porous solid, as water is absorbable by sand; but still air was ever indisputably air, essentially alike and unalterable in its mechanical and chemical oneness. This familiar conception had to be overcome, and the utterly strange notion of the largely aërial constitution of solid matter to be established in its stead, by the early pneumatic chemists, Black, Cavendish, and Bergmann, before the deficiencies rather than positive errors of the phlogistic theory could be perceived.

But long ere the foundation of modern chemistry had thus been laid, in 1756, by Black's discovery of fixed air or carbonic acid as a constituent of mild alkalies and limestone, those old German doctors, Beccher and Stahl, though ignorant of the nature of air, and neglectful of the import of gravity, had yet found something to say about the chemistry of combustion worthy of being defended a century afterward by men like Priestley and Cavendish—worthy, it is believed, of being recognized nearly two centuries afterward as the expression of a fundamental doctrine in chemical and cosmical philosophy. They pointed out, for example, that the different and seemingly unlike processes of burning, smouldering, calcining, rusting, and decaying, by which combustible is changed into incombustible matter, have a community of character; that combustible bodies possess in common a power or energy capable of being elicited and used, whereas incombustible bodies are devoid of any such energy or power; and, lastly, that the energy pertaining to combustible bodies is the same in all of

them, and capable of being transferred from the combustible body which has it to an incombustible body which has it not, rendering the body that was energetic and combustible inert and incombustible, and the body that was inert and incombustible energetic and combustible, and further rendering some particular body combustible over and over again. That this is a fair representation of the views held by phlogistic chemists is readily recognizable by a study of chemical works written before the outbreak of the antiphlogistic revolution. After Lavoisier's challenge, the advocates of phlogiston, striving to make it account for a novel order of facts with which it had little or nothing to do, were driven to the most incongruous of positions; for, while Priestley wrote of inert nitrogen as phlogisticated air, Kirwan and others regarded inflammable hydrogen as being phlogiston itself in the isolated state. Very different is the view of phlogiston to be gathered from the writings of Dr. Watson, for example, who was appointed Professor of Chemistry at Cambridge in 1764, became Regius Professor of Divinity in 1771, and Bishop of Llandaff in 1782. This cultivated divine, indifferent, it is true, to the novel questions by which in less placid regions men's minds were so deeply stirred, amused the leisure of his dignified university life by writing scholarly accounts of the chemistry it had formerly been his province to teach; and in the first volume of his well-known "Chemical Essays," published in 1781, the following excellent account of phlogiston is to be found:

"Notwithstanding all that perhaps can be said upon this subject, I am sensible the reader will be still ready to ask, *What is phlogiston?* You do not surely expect that chemistry should be able to present you with a handful of phlogiston, separated from an inflammable body; you may just as reasonably demand a handful of magnetism, gravity, or electricity, to be extracted from a magnetic, weighty, or electric body. There are powers in Nature which cannot otherwise become the objects of sense than by the effects they produce; and of this kind is phlogiston. But the following experiments will tend to render this perplexed subject somewhat more clear:

"If you take a piece of *sulphur* and set it on fire it will burn entirely away, without leaving any ashes or yielding any soot. During the burning of the sulphur a copious vapor, powerfully affecting the organs of sight and smell, is dispersed. Means have been invented for collecting this vapor, and it is found to be a very strong acid. The acid thus procured from the burning of sulphur is incapable of being either burned by itself or of contributing toward the support of fire in other bodies; the sulphur, from which it was procured, was capable of both: there is a remarkable difference, then, between the acid procured from the sulphur and the sulphur itself. The acid cannot be the only constituent part of sulphur; it is evident that *something* else must have entered into its composition, by which it was rendered capable of combustion. This something is, from its most remarkable property, that of rendering a body combustible, properly enough denominated the food of fire, the *inflammable principle, the phlogiston*. . . . This inflammable principle or phlogiston is not one thing in animals, another in vegetables, another in minerals; it is absolutely the same in them all. This identity of phlogiston may be proved from a variety

of decisive experiments; I will select a few, which may at the same time confirm what has been advanced concerning the constituent parts of sulphur.

"From the analysis or decomposition of sulphur effected by burning, we have concluded that the constituent parts of sulphur are two—an *acid* which may be collected, and an *inflammable principle* which is dispersed. If the reader has yet acquired any real taste for chemical truths, he will wish to see this analysis confirmed by synthesis; that is, in common language, he will wish to see sulphur actually made by combining its acid with an inflammable principle. It seldom happens that chemists can reproduce the original bodies, though they combine together all the principles into which they have analyzed them; in the instance, however, before us, the reproduction of the original substance will be found complete.

"As the inflammable principle cannot be obtained in a palpable form separate from all other bodies, the only method by which we can attempt to unite it with the acid of sulphur must be by presenting to that acid some substance in which it is contained. Charcoal is such a substance; and by distilling powdered charcoal and the acid of sulphur together, we can procure a true yellow sulphur, in no wise to be distinguished from common sulphur. This sulphur is formed from the union of the acid with the phlogiston of the charcoal; and the charcoal may by this means be so entirely robbed of its phlogiston that it will be reduced to ashes, as if it had been burned. . . .

"I will in this place, by way of further illustration of the term phlogiston, add a word or two concerning the necessity of its union with a metallic earth, in order to constitute a metal. Lead, it has been observed, when melted in a strong fire, burns away like rotten wood; all its properties as a metal are destroyed, and it is reduced to ashes. If you expose the ashes of lead to a strong fire they will melt; but the melted substance will not be a *metal*, it will be a yellow or orange-colored *glass*. If you pound the glass, and mix it with charcoal-dust, or if you mix the ashes of the lead with charcoal-dust, and expose either mixture to a melting heat, you will obtain, not a *glass*, but a *metal*, in weight, color, consistency, and every other property, the same as lead. The ashes of lead melted *without* charcoal become *glass;* the ashes of lead melted *with* charcoal become a *metal*. The charcoal, then, must have communicated *something* to the ashes of lead, by which they are changed from a glass to a metal. Charcoal consists of but two things—of ashes and of phlogiston; the ashes of charcoal, though united with the ashes of lead, would only produce glass; it must, therefore, be the other constituent part of charcoal or phlogiston which is communicated to the ashes of lead, and by a union with which the ashes are restored to their metallic form. The ashes of lead can never be restored to their metallic form without their being united with *some* matter containing phlogiston, and they may be reduced in their metallic form by being united with *any* substance containing phlogiston in a proper state, whether that substance be derived from the animal, vegetable, or mineral kingdom; and thence we conclude, not only that phlogiston is a necessary part of a metal, but that phlogiston has an identity belonging to it, from whatever substance in Nature it be extracted. And this assertion still becomes more general, if we may believe that metallic ashes have been reduced to their metallic form, both by the solar rays and the electrical fire."

The foregoing account by Dr. Watson is almost a translation from Stahl's "Zymotechnica Fundamentalis, simulque experimentum no-

vum sulphur verum arte producendi," in which he establishes what may be called the permanency of chemical substance—that metallic lead is reproducible from the ashes of lead, *sulphur verum* from the acid of sulphur. And, whether or not taking note of the oxidations and deoxidations effected, how little differently, even at the present day, would the actions referred to be described and explained! Is it not our habit to say that charcoal and sulphur and lead are bodies possessing potential chemical energy—that is, phlogiston; that, in the act of burning, their energy which was potential becomes kinetic or dynamical, and is dissipated in the form of light and heat; that the products of their burning (including the gaseous product now known to be furnished by the burning of charcoal) are substances devoid of chemical energy—that is, of phlogiston; that, when the acid substance furnished by burning sulphur is heated with charcoal, some energy of the unburnt charcoal is transferred to the burnt sulphur, just as some energy of a raised weight may be transferred to a fallen one, whereby the burnt sulphur is unburnt, provided with energy, and enabled to burn again, and the fallen weight is lifted up, provided with energy, and enabled to fall again; that the potential chemical energy of metallic lead did not originate in the lead, but is energy or phlogiston transferred thereto from the charcoal by which it was smelted; and, lastly, that the chemical energy of the charcoal itself, its capability of burning, its power of doing work, in one word, its phlogiston, is merely a portion of energy appropriated directly from the solar rays?

If this be a correct interpretation of the phlogistic doctrine, it is evident that the Stahlians, though ignorant of much that has since become known, were nevertheless cognizant of much that became afterward forgotten. For most of what has since become known mankind are indebted to the surpassing genius of Lavoisier; but the truth which he established, alike with that which he subverted, is now recognizable as a partial truth only; and the merit of his generalization is now perceived to consist in its addition to—its demerit to consist in its supercession of—the not less grand generalization established by his scarcely-remembered predecessors. This being so, the relationship to one another of the Stahlian and Lavoisierian theories of combustion furnishes an apt illustration of the general truth set forth by a great modern writer, that "in the human mind one-sidedness has always been the rule, and many-sidedness the exception. Hence, even in revolutions of opinion, one part of the truth usually sets while another rises. Even progress, which ought to superadd, for the most part only substitutes one partial and incomplete truth for another; improvement consisting chiefly in this, that the new fragment of truth is more wanted, more adapted to the needs of the time, than that which it displaces."

The partial truth contributed by Lavoisier was indeed more want-

ed, more adapted to the needs of the time, than the partial truth which it displaced. To him chemists are indebted for their present conception of material *elements;* and especially for their knowledge of the part played by the air in the phenomena of combustion, whereby oxygenated *compounds* are produced. The phlogistians, indeed, were not unaware of the necessity of air to combustion, but, being ignorant of the nature of air, were necessarily ignorant of the functions which it fulfilled. To burn and throw off phlogiston being with them synonymous expressions, the air was conceived to act by somehow or other enabling the combustible to throw its phlogiston off; and a current of air was conceived to promote combustion by enabling the combustible to throw its phlogiston off more easily. Moreover, contact of air was not essential to combustion, provided there was present instead some substance, such as nitre, which, equally with or even more effectively than air, could enable the combustible to discharge itself of phlogiston. But, while the phlogistians, on the one hand, were unaware that the burnt product differed from the original combustible otherwise than as ice differs from water, by loss of energy, Lavoisier, on the other hand, disregarded the notion of energy, and showed that the burnt product included not only the stuff of the combustible, but also the stuff of the oxygen it had absorbed in the burning. But, as well observed by Dr. Crum-Brown, we now know "that no compound contains the substances from which it was produced, but that it contains them *minus* something. We now know what this something is, and can give it the more appropriate name of potential energy; but there can be no doubt that this is what the chemists of the seventeenth century meant when they spoke of phlogiston."

Accordingly, the phlogistic and antiphlogistic views are in reality complementary and not, as suggested by their names and usually maintained, antagonistic to one another. It has been said, for example, that, according to Stahl, the product of combustion is simple, and the combustible a compound of the product with imaginary phlogiston —which is false; whereas, according to Lavoisier, the combustible is simple, and the product a compound of the combustible with actual oxygen—which is true. But in this case, as in so many others, everything turns upon the use of the same word in a different sense at different periods of time. When Lavoisier spoke of red lead as being metallic lead combined with oxygen, he meant that the matter or stuff of the red lead consisted of the matter or stuff of lead *plus* the matter or stuff of oxygen. But, when the Stahlians spoke of metallic lead being burnt lead combined with phlogiston, they had the same sort of idea of combination in this instance as others have expressed by saying that the weight of a body is compounded of its matter and its gravity; or that steam is a compound of water and heat; or, to use a yet more Lavoisierian expression, that oxygen gas itself is a compound

of the basis of oxygen with caloric. It is not, then, that the one statement, Stahlian or Lavoisierian, is false and the other true, but that both of them are distorted, because incomplete. Chemists nowadays are both Stahlian and Lavoisierian in their notions, or have regard both to energy and matter. But Lavoisierian ideas still interfere very little with our use of the Stahlian language. While we acknowledge that in the act of burning the combustible and the oxygen take equal part, just as in the act of falling the weight and the earth take equal part, yet in our common language we alike disregard the abundant atmosphere and abundant earth as being necessarily understood, and speak only of the energy of the combustible and of the weight, which burn and fall respectively. Whatever may be the fault of language, however, chemists do not omit to superpose the Lavoisierian on the Stahlian notion. They recognize fully that it is by the union of the combustible with oxygen that phlogiston is dissipated in the form of heat; and, further, that phlogiston can only be restored to the burnt combustible on condition of separating the combustible from the oxygen with which it has united, just as energy of position can only be restored to a fallen weight on condition of separating it to a distance from the surface on which it has fallen.

That Stahl and his followers regarded phlogiston as a material substance, if they did so regard it, should interfere no more with our recognition of the merit due to their doctrine, than the circumstance of Black and Lavoisier regarding caloric as a material substance, if they did so regard it, should interfere with our recognition of the merit due to the doctrine of latent heat. But, though defining phlogiston as the principle or matter of fire, it is not at all clear that the phlogistians considered this matter of fire as constituting a real body or ponderable substance; but rather that they thought and spoke of it as many philosophers nowadays think and speak of the electric fluid and luminiferous ether. The nondescript character, properly ascribable to phlogiston, is indicated by the following quotation taken from Macquer's "Élémens de Chymie Théorique" (1749). It must not, of course, be forgotten that the popular impression as to phlogiston having been conceived by its advocates as a material substance having a negative weight or levity, is erroneous, and is based on an innovation that was introduced during the struggling decadence of the phlogistic theory, and advocated more particularly by Lavoisier's subsequent colleague, Guyton de Morveau, in his "Dissertation sur le Phlogistique, considéré comme Corps grave, et par Rapport aux Changemens de Pesanteur qu'il produit dans les Corps auxquels il est uni" (1762). Macquer writes as follows:

"'Matter of the sun, or of light,' 'phlogiston,' 'fire,' 'sulphur-principle,' 'inflammable matter'—such are the names usually employed to designate the element fire. But no precise distinction appears to have been drawn between fire viewed as a principle in the composition of a body, and fire when it stands

alone and in its natural state. Viewed under the latter aspect, the terms 'fire,' 'matter of the sun, of light, and of heat,' are specially appropriate to it. Under such conditions, it is a substance which may be regarded as made up of infinitesimal particles, agitated by a very rapid and continuous motion, and hence essentially fluid. This substance, of which the sun is, as it were, the general reservoir, is emanating thence constantly, and is universally distributed throughout all bodies known to us, though not as a principle, or as essential to their constitution, inasmuch as we may deprive them of it—at least in great measure—without their suffering the least decomposition in consequence. . . . Yet the phenomena presented by inflammable substances in burning show that they really contain the matter of fire as one of their principles. . . . Let us, therefore, investigate the properties of this fire which has become fixed, and entered as a principle into bodies. To it we will specially assign the name of 'inflammable matter,' 'sulphur-principle,' and 'phlogiston,' to distinguish it from pure fire."

Again, much the same thing is to be found in Baumé's "Manuel de Chymie" (1765); as, for example:

"We consider fire in two different states: when it is pure, isolated, and forming no part of any compound . . . . when it is combined with other substances, forming one of the constituent principles of compound bodies. . . . We have no certainty whether or not fire possesses weight. There are experiments *pro* and *contra*. . . . During the combustion of substances, combined fire is reduced to elementary fire, and is dissipated as the process goes on. The famous Boerhaave, however, is not of this opinion; he says that, were this the case, the amount of elementary fire in Nature must increase *ad infinitum*. . . . But it is easy to reply to this objection by saying that, as we have the right to presume, the elementary fire discharged from bodies combines with other substances, and that it loses all its properties as free fire on becoming a constituent principle of bodies into the composition of which it enters. . . . The principle here spoken of is that to which Stahl has given the name of phlogiston."

In interpreting the above and other phlogistic writings by the light of modern doctrine, it is not meant to attribute to their several authors the precise notion of energy that now prevails. It is contended only that the phlogistians had, in their time, possession of a real truth in Nature which, altogether lost sight of in the intermediate period, has since crystallized out in a definite form. "I trust," said Beccher, "that I have got hold of my pitcher by the right handle." And what he and his followers got hold of and retained so tenaciously, though it may be shiftingly and ignorantly, we now hold to knowingly, definitely, and quantitatively, as part and parcel of the grandest generalization in science that has ever yet been established.

MYRIAPODS.

By MAJOR HOLLAND, R. M. L. I.

"PLEASE, sir, here's one of them nasty mischiefull many-legs as I told you pisened the melon-bed so as we never got nothink off of 'em. Nobody can't say as they wasn't took care of, for I was a waterin' and a waterin' on 'em mornin', noon, and night, all along the droughty summer. It stands reasonable like to natur' as *water*-melons should take a sight o' water; 'twasn't my overdoin' on 'em with m'isture as rotted the roots off; 'twas these here plaguey varmint!"

Having delivered this oration, and proved to his own entire satisfaction "as how he was right all along, and master was mistook" about poor *Curcurbita citrullus* having been drenched to death with icy pump-water, the obstinate old gardener deposited his writhing scape-goat on the study-table, and retired triumphant to the coach-house, where he whistled loud pæans of victory to the Bramahs and Cochins of the stable-yard.

What yellow-brown *Myriapod* is this? His flexible body, which he is tying into all manner of knots, is composed of no fewer than eighty-one distinct segments, to say nothing of the odd one at the end of the tail, and the five which have coalesced to form the head. If we count these five fused segments as one (as we do the four which Prof. Huxley tells us combine together to make up our own human brain-boxes), then his body is made up of eighty-three somites, of which the cephalic, the anterior-thoracic, which bears that terrible pair of hooked maxillipedes, and the anal, are the only three presenting any marked differences from each other, and from the eighty others which are as "strictly uniform" as the helmets of the metropolitan police.

How the fellow shuns the light! Does his conscience trouble him? Does he feel himself guilty of "pisenin'" the melons, that he wriggles so uneasily until he succeeds in burying himself out of sight in the silk tassel of the pen-wiper? A burrowing troglodyte by nature, I suspect, and on closer examination he proves to be such—*Geophilus subterraneus* (underground earth-lover), of the family *Geophilidæ*, of the subdivision *Chilopoda* (foot-feeders), of the order *Myriapoda*, of the class *Articulata*, according to Newport.

He has no eyes; he doesn't want any; he passes his life in the dark, underground, tearing up old shreds of farmyard manure and vegetable matter, always preferring scavengers' work when he can get it, and doing good service by eating up the helpless, soft, succulent larvæ of the hosts of insects that prey upon our crops. The sins of the wire-worm have been laid to his charge; his third cousins the *Iulidæ* do undoubtedly steal our potato "sets," and bore into young peas, or rather into old peas just "spritting" and about to send up

young ones; but it seems doubtful if he himself ever attacks fresh or living vegetables; he seems to be one of Nature's many *vidangeurs*, and, because he is found minding his business and eating up rottenness, he is accused of producing it. As well might we say that our sewer-men produce typhus and cholera. But he has even been charged with having *caused* the potato-disease! because he was found laboring to remove the affected tubers. Beware, ye brave surgeons who fight with zymotic demons and risk your own lives to lift up stricken humanity, lest ye be arraigned for *producing* all the long catalogue of human ills that figure in our sanitary statistics!

Our captive has no eyes; he has, however, an "ocellus," a mere pigment-speck behind the base of each of his fifteen-jointed antennæ, and he has the smallest possible threadlet of an optic nerve. I suspect he cannot see, in the ordinary sense, but can distinguish between the light with which he has nothing to do, and the darkness in which he feels his way about with his antennæ when doing his duty like a humble vegetarian jackal, or adjutant.

The *Myriapods* have been placed at different times in different classes of the animal kingdom. In one famous system we find them under the head of *Crustacea;* another, in remote times, ranged them with the *Hemiptera* and *Orthoptera* as "insects which only undergo a partial metamorphosis." They have slight affinities with both, and even with the *Annelids;* like the latter, they grow in length by the successive addition of new segments between the penultimate and anal. The lower subdivision, the *Chilognatha*, by the situation of their reproductive orifices, seem to betray *Crustacean* relationships; but we remember that, in the first phase of their development, they displayed three pairs of legs only, like the typical hexapod *insect.* They appear to stand out the strong, well-marked, first link of that long chain which bridges over the mighty gulf which rolls between the creeping worm and the flying insect. The *Myriapod* is the lowest *articulate* animal, the *Annelid* the highest *annulose*—i. e., according to the old scheme of classification, the latter term has recently been used with a widely-extended signification. Ten years ago the subdivision *Chilopoda* consisted of four families, including ninety-four genera; and the lower subdivision, *Chilognatha*, of four families, containing seventy-five genera; a tremendous total of variations of a type; but since then they have been shuffled and cut, and lumped and split, like the German states, till nobody knows which is which.

"An *articulation* complete in all its mechanical appliances is not produced in the animal kingdom below the *Myriapod.* A *joint* is the symbol of organic superiority; it is not an arbitrary symbol; it is a unit in an assemblage of signs which proclaim a newer and higher combination in the arrangements which constitute 'life.' At this limit in the animal series the fluids and the solids of the organism undergo a signal exaltation of standard. The system of the chylaqueous fluid

exists no longer in the adult organism, it is present only in the embryonic. It is supplanted by that of the blood proper. Coincidentally with the 'joint' at the frontier of the articulate sub-kingdom there occurs a heart to circulate the blood, fibrine, and with it an order of floating corpuscles more highly organized in the fluids; a wondrous development of the muscular apparatus, striæ in the muscle-cell, a rapid increase in the dimensions of the cephalic ganglia, and in those of the organs of the special senses. It is here in the history of the reproductive system that the diœcious character is first unquestionably assumed. These are noteworthy events in the ascensive march of organic architecture."—(Dr. Williams, *Magazine of Natural History*, 1854.)

The armor-plates of the cylindrical *Iulus* are composed of a semi-crustaceous hard substance, but in the *Scolopendridæ*, which our "false wire-worm" closely approaches, the integuments are of a flexible chitinous substance, the back of each segment is covered by a plate, the ventral surface by a somewhat smaller plate, the epimeral portions, as well as the interspaces between the somites, are covered by a loosely-fitting coriaceous membrane of much thinner texture.

The circulating system has been a battle-ground for men with great reputations. The nervous and reproductive systems, and the development day by day from the ovum, have been drawn out with elaborate minuteness by Newport, in "Philosophical Transactions" for 1841 and 1843, but I have not fallen in with a drawing of their tracheary system, which is well worthy of careful study.

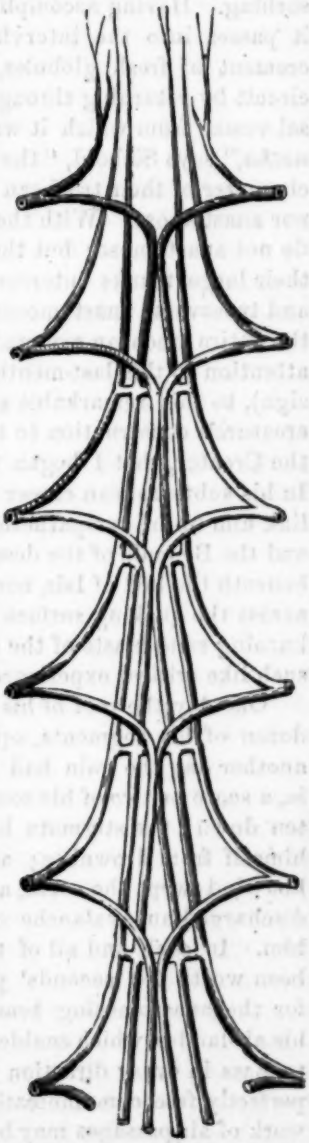
The spiracular orifices are not placed as in insects between the segments, but in the side of each, a little below the dorsal plate; they are not minute apertures, nor vertical slits, neither are they furnished with "guards" of setæ, or hairs, to exclude dust and foreign bodies; but they are circular openings, each with a well-defined, hard-looking ring, over which the tough but pliable lateral membrane passes, lining the entrance, which is directed slightly backward, and can be closed by a sphincter-muscle. The tracheæ are very large in the anterior segments, occupying no small portion of their internal cavities, but they decrease in diameter in proportion as the segments recede from the head; possibly there may be need for a more abundant supply of oxygen in the region of the brain, and in the first-formed portions of the body, than in the equally large but more remote additions which are from time to time developed near the caudal extremity.

Let us detach half a dozen pairs of spiracles, with their tracheal appurtenances complete, from the dissected tail-end of *Geophilus* the much maligned, float them on to a slide, and bring the "two-thirds objective" to bear upon them.

A ladder of shining silver, a very Jacob's ladder, bright and beautiful enough to have been let down from heaven for the feet of angels.

The six uprights and the cross-rungs are all constructed of the same tubular wire rope glistening with a dazzling metallic lustre, and

without a flaw anywhere. The tubes are composed of an outer and an inner coat, containing between them the spiral coil, to which they are closely attached; a delicate membrane also connects the turns of the spiral with each other. It is interesting to compare these animal breathing tubes with their analogues *the spiral vessels* of the vegetable kingdom; the latter are easily extracted from the young shoots of asparagus, or from the leaves of the hyacinth. The spring-like coil insures a free open passage for the air which rushes in by the spiracular orifices, expiration being effected by the contraction of these elastic channels, by which the effete air is forcibly expelled through the openings by which it originally entered.



Tracheæ of Geophilus Subterraneus. Magnified 140 diameters.

The main tracheæ pass down the axes of the blood-channels, floating in the vital fluid, which they revivify with the oxygen which they thus carry to and through the life-stream. We are told that the air-pipe does not terminate where the wiry-looking spiral comes to an end; the latter dwindles away imperceptibly to nothing, but the trachea thence becomes membranous, and, dividing into innumerable branches, which bear to the main trunks the same relations that the capillaries bear to the arteries, penetrates the substance of the muscles, inconceivably fine branches having been traced accompanying the nerves, while the ultimate plexiform extremes of the system aërate immediately the solids. "In all the transparent structures of insects every observer may prove for himself that the blood-currents travel in the same passages as the tracheæ, but this is only the case with the primary and secondary branches, *never* in the capillary tracheæ; the blood-corpuscles of the *Myriapod* exceed by several times in diameter that of the extreme capillary membranous tracheæ; it is perfectly marvelous to what inconceivable minuteness the air-current is reduced in traveling along these tubes." What a simple and efficient plan, what an economy of space is this arrangement of tube within tube, for aërating the blood in a class

of lowly, creeping things of earth that do not attain to the dignity of lungs! There is a saving of time, too, for the blood is made arterial while on its journey, and thus travels direct (without the delay of passing off to special pulmonary organs) to the performance of its functions, removing, replacing, renewing, sustaining, building up, absorbing. Having accomplished these, and become as it were venous, it passes into the intervisceral spaces, and there, receiving an increment of fresh globules, the products of digestion, completes its circuit by returning through distinct valvular openings into the dorsal vessel from which it was first distributed. "Among the *Chilognatha*," says Siebold, "the *Iulidæ* are noticeable for the very simple character of their trachean apparatus; their air-canals neither ramify nor anastomose. With the *Glomerina* the tracheæ are branched, but do not anastomose; but those of the *Chilopoda* are very ramose, and their large trunks intercommunicate at their origin by longitudinal and transverse anastomoses, so that each stigma can introduce air into the entire trachean system." It was chiefly with the view of drawing attention to this last-mentioned fact (a most striking evidence of design), to this remarkable example of the exquisite adaptation of the creature's construction to the condition of existence ordained for it by the Creator, that I began this bit of simple gossip about *Geophilus*. In his subterranean career he constantly meets with accidents which link him up in sympathetic association with Brunel and Stephenson, and the Bedouin of the desert. He never bored a practicable highway beneath the bed of Isis, nor made firm the foundations of an iron road across the quaking surface of Chat Moss; neither has he braved the burning sand-blasts of the simoom; yet in his degree he has met with such like critical experiences a hundred times.

One day the roof of his tunnel crashed in upon him, and buried a dozen of his segments, squeezing the very breath out of them; on another day the rain had saturated the rubbish-heap he was toiling in, a score or two of his somites were under water, and he had to "batten down" the stigmata belonging thereto to save those portions of himself from drowning; and yet, again, in the scorching dog-days, a hot wind swept the earth, and a dry and thirsty clod, crumbling away, discharged an avalanche of dust which overwhelmed nine-tenths of him. In each and all of these catastrophes his life would not have been worth ten seconds' purchase, even with his many spiracles, but for the anastomosing branches of his windpipes, the cross-rungs of his air-ladder, which enabled the air received by the unchoked segments to pass in every direction through the whole system. That there is perfectly free communication from any one spiracle to the whole network of air-passages may be seen by examining the figure which I have given; and if any reader has still a doubt on his mind he may remove it, if he is a dexterous manipulator, by dissecting out the tracheary apparatus of the first *chilopodous Myriapod* he can lay hands on;

and, stopping the orifices of all the spiracles but one, he will find that through that one he may inject the whole labyrinth of air-vessels with carmine.

I observed that a correspondent, J. G. D., in December last, was much surprised at the display of a phosphorescent light by a centipede he had found. *Geophilus electricus*, a member of the same family, and a near relation of our *Subterraneus*, must have been the pyrotechnist he chanced upon. "The caustic brown fluid which most *Myriapoda* when touched emit from a row of orifices, *foramina repugnatoria*, situated on the sides of the segments of the body, and which exhales an odor like that of chlorine, is secreted by small pyriform glandular follicles situated immediately beneath the skin; it is from glands upon the sides of the body analogous to these that *Geophilus electricus* emits a luminous liquid."

It would be most interesting to ponder over the three varieties of breathing apparatus mentioned by Siebold, and to note their special adaptations to the life conditions and necessities of the three distinct genera provided with them; and there are other wonders in the ways and mechanism of each and all of them that one longs to dwell upon; but we are not essayists here, only cheerful "gossips" of the wayside, who seek to be merry and wise, accurate, though simple and amusing. We have run to the end of our tether, and must say good-by to *Geophilus subterraneus* and all the *Myriapods.—Science-Gossip.*

SOAP-BUBBLES.

By Prof. RÜCKER.

IN the museum of the Louvre, in Paris, there is a vase which has by some strange chance been handed down to us through the long ages which have proved fatal to many others far more worthy of preservation than itself. It was manufactured in Italy—before the foundation of the city of Rome—by the ancient Etruscans, and it is decorated—and this is the reason I bring it to your notice this evening—with a design representing a group of children blowing bubbles. This ancient relic of those early days incontestably proves to us that the art of performing that beautiful experiment, if not with soap and water, at least with some one of the comparatively few liquids with which it can be satisfactorily undertaken, has been known at least for twenty-five hundred years. But, though generation after generation the children amused themselves with it, century after century passed away, leaving unanswered, and in all probability unthought of, the

[1] A lecture delivered in the Hulme Town-Hall, Manchester, on Wednesday, November 3, 1875.

numerous questions which it cannot fail to suggest to us. Why is it so easy to blow bubbles with some liquids, and so hard to form them with others? Why does a bubble when blown at the end of an open tube gradually contract and disappear? Why, when it bursts, does it not still remain a liquid film, but is shattered to an almost imperceptible dust? These and a hundred others remained unanswered, and, as I have said, perhaps un-put, until after the genius of Newton had attacked the far more difficult problem of the colors which bubbles display. To night, however, I hope to be able to give you the answers to some of these so long-delayed inquiries, as it is now perhaps two hundred years since men of science began to turn their attention to the phenomena of liquid bubbles, and of those properties of liquids on which they depend, and their efforts have been rewarded with no small measure of success, although it is certainly only within the time of many of us here that they have been able to give anything like a complete explanation of them all. In order, however, that we may understand how best to study the laws and constitution of a soap-bubble, it is necessary that we should in the first place clearly comprehend what it really is. We all know how soap-bubbles are ordinarily formed. A common tobacco-pipe is dipped into a mixture of soap and water, and when it is withdrawn a thin liquid film stretches across the mouth, which we can blow out into a bubble, and then shake off and detach from the tube. I will now perform the experiment of blowing a bubble before you; only, instead of employing a tobacco-pipe, I will use this glass funnel, and for the common soap and water I will substitute a mixture of Castile soap, water, and glycerine. [A large bubble was speedily blown, and it showed the usual beautiful colors. This and the succeeding experiments were dexterously and successfully performed, and were much applauded].

You now see how, by using a proper liquid, and by taking proper precautions, we are able to obtain bubbles of enormous size. But I wish you for a moment to confine your attention to the bubble, not in its full-blown beauty, as you saw it just now, but rather in that stage in which it was merely a thin film covering the mouth of the funnel. Now, this film was originally the topmost layer of that portion of the liquid inclosed by the funnel, which as I withdrew it skimmed off a thin slice from the surface—a slice so thin that had I allowed it to drain for a while its thickness would not have exceeded four millionths of an inch. But, although the total quantity of liquid contained in it was so small, the surface of the film was no less than twice the area of the orifice of this large funnel. Hence, both from the method of formation of the film and from its constitution when formed, it is evident that, if, in any respects, the surface of a liquid differs from the internal mass, if there are laws which govern and forces which are at play on the surface, the effects of which we do not recognize elsewhere, these peculiar properties must be to us of primary importance, if we

would understand the theory and constitution of a soap-bubble. The course which I shall adopt this evening is, in the first place, to study the laws and forces which are in operation on the surface of a liquid, and after that I shall try to show you how they may be used to explain the phenomena which we observe in the short but brilliant life of a bubble.

I have upon the wall a diagram on which three of the principal properties of the surface of a liquid are enunciated. That to which I wish first to draw your attention is that the surface of a liquid is in a state of tension. It is necessary that before we go any further you should have a clear comprehension of the meaning of this word "tension." I have here a piece of India-rubber, and if I stretch it with my hands I throw the whole of it into a state of tension. The peculiarity of this state is that, if I were to divide the India-rubber into two portions with a sharp knife, the parts, no matter where the incision was made, would instantly fly in opposite directions, and each would become shorter. But what each of those parts would then actually do—that is, contract or become shorter—each is now tending to do; but, since it could only become shorter by elongating the other part, and as that is pulling in an opposite direction with equal force, the two forces neutralize one another, and the whole remains in a state of rest, and also in a state of tension. If, then, we generalize from this particular instance, we may define a state of tension as follows: that a body is said to be in a state of tension when each of any two parts into which it may be divided tends to contract and to expand the other. You observe, then, that the tendency of one part to extend the other is the criterion of a state of tension; and I will now show you a couple of experiments which will, I think, enable me to prove that it exists in the surface of a liquid.

I have here a small iron ring, and stretched loosely across it, from side to side, there is a piece of cotton. I dip it into a vessel containing some of the soap-mixture I used just now, and it comes out with a film adhering to it precisely in the same way as the funnel did. I now show you upon the screen the image of the ring, with the thread stretching across it, and resting upon the thin liquid film. If what I have just been saying be true—if each portion of the film be in a state of tension—then each of the parts into which the thread divides it is tending to contract and to expand the other. Thus, the thread is acted upon by two forces: the portion of the film to the right is tending to pull it to the right, and the portion on the left is tending to pull it to the left; but, inasmuch as these two tendencies are equal and opposite, the effect upon the thread is as if they did not exist; that is to say, it will remain at rest in any position on the film. I will now move the thread about on the film with a wire, showing that it will remain wherever I place it. I distort it and put it in any position I like. Let us, however, consider what will happen if I break

the film upon one side of the thread, and leave it uninjured upon the other. The surface-tension, destroyed upon one side, will remain in action in the unruptured film, and therefore we should expect the thread to be pulled toward the uninjured side. We can easily put the matter to the test of experiment. I break one side by touching it with a hot wire, and what we foresaw occurs, the thread is instantly pulled toward the side which the wire did not tear. This experiment proves that the surface of a liquid is in a state of tension. I have, however, another experiment to show you upon the same point, which will add to our knowledge upon the subject, for it will not only show that the tension exists on the surface, but that in different liquids it exists in different degrees of intensity. You now see upon the screen the image of a few drops of colored water, which are placed upon a glass plate. I dip a glass rod into some pure water, and touch the colored film with the drop which adheres to the end. As you see, nothing very particular happens. There is only a slight diminution of the blueness in the centre, owing to the fact that the colored water has been mixed with the pure water. Now, I will dip the rod into alcohol, and you will see a different result. As soon as I touch the blue water with the alcohol a motion occurs, and it moves rapidly away from the point at which the contact took place. Now, let us consider shortly what the explanation of this phenomenon is. The surface of the water and the surface of the alcohol are alike in a state of tension; but the tension of the surface of the water is greater than that at the surface of the alcohol. At the moment I put the drop of alcohol upon the water we had a small drop of alcohol surrounded by a large quantity of water, and between the two there was a line of demarkation, which we may, for simplicity's sake, liken to the thread you saw just now. When I destroyed the force of the tension in the first experiment on the one side, the force which remained on the other side pulled the thread toward it. In this case the force was acting on both sides; but the force at the surface of the water pulling away from the centre of the alcohol-drop was greater than the force at the surface of the alcohol-drop pulling toward its centre. The consequence was, that we obtained a motion in the direction in which the greater force was acting—that is, in the direction in which the water was pulling away from the centre; and this continued—the water and alcohol moving farther and farther away, until the two became entirely mixed together. An experiment similar to this may be performed after dinner in the evening: When we pour some wine into a glass we generally in doing so wet the sides, and the result is, a thin film of liquid adheres to them above that portion of the glass which is filled with wine. This film soon contracts into drops, and each of these drops consists, as all wine does, of a mixture of water, alcohol, and certain other substances, the presence of which we may for the moment neglect. Alcohol, as you know, is an extremely volatile fluid,

which evaporates very rapidly, and therefore above the surface of the liquid there is a small atmosphere of alcohol formed by evaporation from the wine. This evaporation goes on in the drops as well as in the main body of the wine, but more rapidly at the upper surface of a drop than at the lower; the reason being that the lower part is more completely immersed in the little cloud of alcohol which hangs over the wine itself. A drop is thus formed composed in the upper part of water, with comparatively little alcohol, and in the lower part of water with a larger proportion of alcohol. The experiment I have just shown proves that the tension in the upper part must be greater than that in the more alcoholic or lower portion of the drop. Hence you may often see drops of wine actually running up the side of a glass, in obedience to a force exerted in an upward direction, by the greater surface-tension of the portion containing the larger percentage of water. A very important deduction may be made from the fact that the surface of a liquid is in a state of tension. You saw in the first experiment that, as soon as the film on the one side of the thread was broken, that on the other side contracted very rapidly, and took up a form with as small a surface as was possible under the circumstances. If we were to generalize from this particular instance, we should be led to the conclusion that, because the surface of a liquid is in a state of tension, and thus each part of it is tending to contract, therefore it will always assume a shape which will have the smallest possible surface. I will now show an experiment to illustrate this fact. I have here a tube formed of four plane pieces of glass, through which I shall be able to send light, and so show you the image of its contents on the screen. It forms, in fact, a little box of glass, the ends of which are open, one of them being considerably narrower than the other. I now put the larger end of this tube into a mixture of soap and water, and I withdraw it with a film adhering to it. This film has a tendency to assume that shape which has the smallest possible surface; and evidently, by moving up the tube toward the narrow end, its surface can be made smaller than it is at present. You now see on the screen an image of the tube. I move it for a moment in order to form the film. You now see the image of the film, and I think you will observe that it is slowly moving up the tube, and therefore that its surface is becoming smaller and smaller. The experiment might be prolonged until the film burst; but, at all events, you have there sufficient proof that it moves into a position in which its surface is diminished. And, further, inasmuch as the image of the tube is turned upside down on the screen, what appeared to you to be a motion from above to below was, in fact, a motion from below to above; the film was in reality moving upward, although to you it appeared to be moving down. It was really raising its own weight instead of being pulled down by it. We have thus now established this quality of

liquids, namely, that their surfaces tend to become as small as possible, and we may extend the law to another and very interesting case.

Let me suppose for a moment that I take a mass of clay: it is evident that I could mould it into an infinite number of different forms; each of these forms might have precisely the same volume, might occupy exactly the same space, but they might all have very different surfaces. For instance, if I took a rolling-pin and rolled the clay out into a thin disk, and then compressed it into a round ball, it is evident that, although the volume might be precisely the same in the two cases, the area of the surface would be much greater in the disk than in the ball. Now, in the experiment I showed you last, the film moved up the tube, because it had a tendency to diminish its surface as far as possible; but, if I had continued the experiment longer —if I had allowed the film to move up to the narrowest part of the tube, it would, even then, only in part have satisfied this tendency, and not have done so completely—it would have attained the smallest surface possible under the circumstances, though not the smallest possible surface. The reason why it would not have done so is this: that forces were acting upon it other than that which tended to make it contract, for it was also affected by the force of adhesion to the sides of the glass tube; and, as a matter of fact, liquids are ordinarily subjected to the action of no less than three distinct sets of forces. The first of these is the attractive influence of the earth, or the weight of the liquid; the second is the adhesion of the liquid to the sides of any solid vessel in which it may be contained; and the third class comprises those forces which are at play in the liquid itself. It is evident, then, that the form which a liquid takes will not be due to any one of these, but to all three. The form which it would assume if left to the action of its molecular forces will be modified in the first place by its weight, and in the next by the adhesion to the sides of the solid vessel. Hence the question arises, if we take a liquid free from both these disturbing forces—free from the attractive influence of the earth, or practically so, and free also from the force of adhesion to the side of the solid vessel—which of all the possible shapes into which I might mould my mass of clay would the liquid assume so as to have the smallest possible surface? This question we are able to answer very easily by means of experiment, and the method by which we do so depends upon the application of an extremely simple principle. When we place a stone in a mass of water we have, in order to immerse it entirely, to push aside, to remove to the right and left, a certain quantity of water, the volume of which is precisely equal to the volume of the stone; and the stone sinks to the bottom, because its own weight is greater than the weight of the water which it has so displaced. A piece of cork, on the other hand, would rise to the surface, because its weight is less than the weight of the water equal in volume to itself.

If we could obtain a body the weight of which was precisely the same as the weight of the water it displaced, it would have no tendency to sink or swim, but would remain at rest in any part of the water into which we might choose to place it. Hence this body would be practically free from the attractive influence of the earth, and we should have succeeded in neutralizing the force of gravity, since a body having no tendency to rise or fall might be considered as removed to such a distance from the earth as to have no weight. Of course, this conclusion is independent of the fact whether the body introduced into the water is a liquid or a solid, and we may substitute for the water any other liquid; but, if we employ two liquids, they must satisfy the following conditions: In the first place, they must not mix together, as wine and water do, but must remain separate, like water and oil. In the second place, the weight of any volume of one must be exactly equal to that of the same volume of the other; and, in the third place, the two liquids must have, when in contact, no chemical effect upon each other. Could two such liquids be found, a small quantity of the one introduced into a mass of the second would be a state eminently favorable for determining the shape which it would assume under the influence of its surface-tension alone. It would, as I have pointed out, be free from the attraction of the earth, and it would also be free from the force of adhesion to the sides of a solid vessel. It would, however, be extremely difficult to find two liquids which would satisfy these conditions; but, although we cannot find them to our hand, we are able to manufacture them. Water is a liquid which is heavier than oil, and alcohol is on the other hand lighter than oil; and, if we mingle water and alcohol, we may make a mixture, the weight of any given volume of which is precisely equal to that of the same volume of oil, and by introducing a few drops of oil into the mass of alcohol and water of the right density we ought to succeed in observing the form which a liquid assumes under the influence of its surface-tension alone. You now see upon the screen the image of a mass of oil in a mixture of alcohol and water of the kind I have just described; and you see that our question is at once answered—the oil assumes a spherical form. From this we learn that a liquid, if left to the action of its surface-forces alone, will become a sphere. But inasmuch as the effect of the attractive influence of the earth, or the weight of the liquid, increases with the quantity we use, while on the other hand the surface-tension, or its own moulding molecular force, remains precisely the same, we should, if we use a large quantity of liquid, expect the weight to be the particular force which determined its shape; and if we employ a small mass of liquid, then the surface-tension, growing proportionately greater, would become the more important. Thus it follows that, although we have to use the most accurate adjustment in order to obtain a sphere of oil an inch in diameter, every rain-drop, every dew-

drop, and every soap-bubble, is in itself almost a mathematically accurate sphere. It is very possible, of course, to make a liquid assume any number of other shapes you please, but I wish now to draw your attention to the fact that we are able to give it another very simple form, namely, that of a cylinder: and I will show you upon the screen the conversion of a spherical soap-bubble into a cylinder. You now see the image of a glass funnel. I take another of precisely the same dimensions, and blow upon it a small bubble, which I make adhere to the first, and then I draw it out into a very accurate cylinder. This proves that the form of a quantity of liquid may, under proper conditions, be cylindrical; but if we make the cylinder of such dimensions that the length is very considerable in proportion to the breadth, then the liquid will only retain the cylindrical form for a very short time indeed. The slightest jar or disturbance of any kind will of course make it deviate from its shape, and that deviation when once begun is continued, as it were, by the liquid of its own accord. The series of transformations through which the cylinder will go, I have represented for you in the diagram. At the top is the long cylinder, which represents the liquid in its first state. Assuming that it is slightly disturbed, you see that it swells out in some places and contracts in others; and the elevations and depressions grow greater and greater, until the mass of the liquid becomes, as in the lower figures, little more than a series of balls tied together by very fine liquid threads. The transformation does not end here; the threads are soon broken, and thus what was originally a continuous cylinder is transformed into a series of alternately large and small spheres. I shall have to make use of this particular transformation of the cylinder later in my lecture; but I wish for the moment to call attention to the fact that one very interesting instance of it is observed whenever water flows out from the bottom of a vessel through a small circular hole. In such a case the form of the column of water would be approximately that of a long cylinder. But, as I have already pointed out, this is a state of what is called unstable equilibrium—of equilibrium which may exist for an instant, but not for a longer time. Hence the above series of transformations are gone through. We have alternately contraction and elevation; these go on until at length the falling column of water is broken up into a falling column of drops.

We must now, however, pass on to another property of the surfaces of liquids, namely, that they press on the liquid, or air which they contain, in much the same way as a blown-out bladder presses on the air within it. I will show you an experiment illustrating this in the following way: If a bubble presses on the air within, then it is evident that, if we made a hole in its side, the tendency of the compressed air would be immediately to escape through the hole, and we should have a current of air flowing out of the bubble, which would

thus become smaller. I will blow a bubble at one end of a glass tube, and leave the tube open at the other end; we shall thus have a small hole formed in one side of the bubble, which, if our theory is correct, will gradually contract and disappear. You now see on the screen images of the ends of two tubes. I have the power of cutting off one tube entirely from access to the other; and I do so now, so that you will, if you please, consider for the purposes of this experiment that tube only as existing at the extremity of which I shall blow the bubble. You now see the image of the soap-bubble, which as long as the tube is closed remains unaltered in size; I open it, and it now at once contracts and disappears. This, then, conclusively proves that the air in the bubble was compressed. I will now go a step farther, and show that the amount of this compression depends on the size of the bubble. If it be large, the air is not so much compressed as if it be small. Let us consider what would happen if I formed bubbles at the two ends of a tube. If they were of the same size, evidently —the one pressing the air in one direction, and the other pressing it in the other with equal force—no effect would follow. If, however, one bubble were smaller than the other, and what I have said be true, the small one would compress the air within it, and drive it from left to right (say) with greater force than the other would tend to drive it from right to left; hence the air would flow from the small bubble to the large one; the large one would increase, and the small one diminish. The smaller the bubble, the more the air would be compressed; and thus the current would become greater and greater, until at last we should see the small bubble entirely disappear, the large one having absorbed all the air which it previously contained. I will try to show you this on the screen; first disconnecting the two tubes, I blow at their ends bubbles of unequal size. I will now place them in communication, so that the air can pass from the one to the other. You see, the small bubble contracts and the large one expands, and we thus learn that the pressure of the smaller or more curved bubble upon the air is greater than that of the less curved one.

I now come to the third property of liquids of which I wish to speak; and that is, that the surface of a liquid is generally either more or less viscous than the interior. With reference to the word viscous, you will find a familiar example of two liquids which differ very much in this property of viscosity in treacle and water. Take a vessel of treacle and a vessel of water, pour the liquids out, and note the different way in which they behave; the water flows out smoothly, one part slipping over another, whereas the treacle comes out in a great rolling mass, which seems to stick to the sides of the vessel. Again, put a spoon into a vessel of water, and move it through the liquid, you will find little resistance to its motion, the water seems to flow away to make room for it and closes in again immediately behind. Try the same experiment with the treacle and you will find the resist-

ance very much increased; in front of the spoon a little heap of liquid gathers, which subsides but slowly, and there is a depression behind which is as slowly filled up. It is evident that there is some difference between the interior constitutions of the treacle and the water; and that difference consists in this, that the particles of which the treacle is composed move among themselves with very much less facility than do those of the water. The fact, then, of one part of a liquid moving more or less easily among the other parts is that which distinguishes one from another in respect to their viscosity. In a very viscous body, like treacle, the parts move with difficulty; and in a non-viscous liquid, like water, they move with comparative ease. The fact which I wish to impress upon you this evening is, not that one kind of liquid differs from another; but that one part of a liquid may differ from another in respect of viscosity; and that as a general rule the surface is more or less viscous than the interior. I will now show you an experiment which will illustrate this fact in a very striking way. I have in a glass vessel a little magnet, which, when I bring near to it a large magnet, will easily and readily follow its motions. The vessel also contains a mixture of water and a substance called saponine. This saponine is extracted from the horse-chestnut, and is, as far as I know, chiefly interesting on account of the extraordinary effect it produces on water when mixed with it. In making the mixture, I have added only one part of saponine to sixty of water, and, to look at, it retains the properties of water; it is colorless; it has none of the viscosity of treacle. In fact, the saponine has next to no effect on the interior parts of the water, but it has a most extraordinary and marked effect on the surface; and that I will now try to illustrate. You now see upon the screen the image of the magnet, and the vessel at the bottom of which there is the mixture of saponine and water. The magnet is at present about an eighth of an inch above the liquid. I bring near the large magnet, and you see how easily it follows its motions. I will now pour in some of my mixture until the magnet lies upon the surface, and I then again bring the large magnet near it. It is now upon the surface of the mixture, and you can see some of the bubbles formed as I pour the liquid in. I bring the large magnet as near as it was at first and am moving it, but it produces no effect. I bring it nearer and nearer—still no effect. I bring it so near that you can see its shadow, and still the magnet remains absolutely motionless. On the surface of the liquid, then, we have found that the little magnet is totally insensible to the attractive force of this large one. You may say that the same would happen in the case of glycerine or treacle. It might; but now comes the extraordinary part of the experiment. I pour in some more saponine and water, until the little magnet lies a quarter of an inch below its surface; I then bring the large magnet near, and you see the result.

It moves almost as freely as in the air itself. Hence we have a

most convincing proof that the surface-viscosity of this solution is very much greater than the viscosity of the interior of liquid; and that the resistance offered to motion by the surface is many times larger than that experienced by moving bodies in the interior.

Another experiment will illustrate this enormous surface-viscosity of the mixture of saponine and water in a still more striking way. I have already explained to you that if we blow a bubble at the end of an open tube, the bubble will gradually contract until all the air is expelled. What, however, will occur if, instead of simply allowing the bubble to drive the air out, I suck the end of the tube and draw it out more quickly? I will first perform the experiment on some of the soap and water I have used before, and you will see that, although the bubble will contract more rapidly than before, it will retain throughout the whole of the experiment its spherical form. I will now repeat the same experiment with saponine and water. In this case, on account of the great viscosity of this thin film it will be unable to follow the retreating air as quickly as it must do to retain its spherical form; the consequence is, it will be unable to retain that form, and it will therefore collapse and wrinkle up into a purse-shaped bag.

I hope I have succeeded in proving to you that these three properties of liquid surfaces exist. I must now go on to explain how they can be applied to the theory of soap-bubbles. Let us suppose, in the first place, that a bubble is rising in a vessel of water. It will tend to assume a spherical form; but as it rises to the surface it will be flattened in the direction in which it is moving, and, instead of being a perfect sphere, it will be longer in one direction than the other. Evidently, as it moves, it has to displace the water in front of it, which flows away to the right and left out of the way of the bubble. But, as I have explained, all liquids offer a certain amount of resistance to the motion of one part upon another; and, although the resistance offered by water is extremely small, it must be taken into consideration. The liquid, therefore, has to flow out of the way of the advancing bubble, and to overcome the resistance offered to its motion; but as the bubble rises nearer to the surface it moves faster and faster, and therefore the water must be removed from its path more and more quickly. But the resistance offered to its motion becomes greater the faster it moves; hence you have the bubble rising more quickly, the water being obliged to get more quickly out of the way, and finding more and more difficulty in doing so, and having, when the bubble gets very near the surface, less space between the bubble and the surface to flow away in. The result is, that the water cannot get out of the way, and therefore the bubble carries it up with it and forms a thin liquid film, which we see as foam upon the surface, through which the bubbles of air are rising. Supposing the bubble thus formed were placed upon a solid plate, it would have the form of half a sphere; and, as the bubble compresses the air in it, the air

would press upon the plate; but the plate would be able to resist the pressure, and the bubble would remain a hemisphere with a flat base. If, on the other hand, the bubble were formed on the surface of a liquid, there would be precisely the same pressure on the bottom, only it would be acting on a medium which would give way to it; the liquid, therefore, would yield to the pressure of the air, and we should have the bubble as it were a little buried in the liquid by its own pressure. As the pressure increases with the smallness of the bubble, we should expect a small bubble to be very deeply buried, and a large bubble to be slightly buried. I will now pour into the cell, the image of which you see, a small quantity of liquid, and blow in it a very small bubble. You now see the images of two bubbles which have risen to the surface, and that they are very much buried in the liquid by virtue of their pressure. I will now blow a large bubble. You see that within it the surface of the liquid is very much less depressed. I will blow a still larger one. Now I have succeeded in blowing a very large bubble, and the lower part of it is not appreciably depressed. I will now blow a great number of bubbles in contact, and will then point out one or two facts. You now see that odd network which represents a great number of bubbles. There are two points I wish you to notice. In the first place, when two bubbles meet, the surface between them may be either plane or curved. It is plane if both bubbles are of equal size, and therefore compress the air within them with equal force; but, if they are unequal, the smaller bubble, compressing the air more strongly, indents the larger, and the surface which divides them is curved. Notice also another very curious point, namely, that in no case do more than three bubbles meet in a point, excepting for an instant. This follows from the law that a large number of bubbles, as well as each one, will assume the smallest possible surface. I cannot go into the proof of this, but it follows from the law I have already given you. As the bubbles form, collapse, and disappear, you see that they always so arrange themselves that no more than three shall ever meet in a point.

Now, then, we have got our bubble on the surface of the liquid. Let us consider what will happen to it after that. Evidently the liquid of which it is composed will run down the sides by virtue of its own weight; but there will be a certain resistance to this motion, greater or less as the viscosity of the surface is great or small. Hence, there are two different dangers which may beset the bubble. The first of these is, that when the surface-viscosity is small, then the liquid runs down the sides of the bubble very easily; the consequence is, the bubble becomes very thin and bursts. There is, however, an opposite danger which may imperil the bubble when the surface-viscosity is great; and that is, that the liquid does not flow down in a straight line or regular curve, but in irregular masses, which every now and then tear away from each other. Now, these ruptures make

little holes in the surface of the liquid; and when a hole is made the surface-tension tends to tear the liquid away, and to make it bigger. If the liquid has a very considerable surface-tension, the small holes in the surface may be so instantly turned into large ones that the bubble may burst. This is, however, less likely to occur when the surface-viscosity is small than when it is great, because in that case the liquid flowing in from all sides can more easily fill up the hole, and restore the damage done, before it becomes dangerously large. The best kind of bubble for lasting is one in which the surface-viscosity is tolerably large, so that the sides of the bubble may not become thin too quickly, and in which the surface-tension is not too great, so that any small fractures which occur may not be instantly enlarged. When we find a liquid which has these two properties, we have all the requisites for making good bubbles; but sooner or later a hole is made, and then the bubble bursts, and in a way which is probably very different from what, *a priori*, we should expect. In the first place, the orifice which has been formed becomes rapidly larger, the surface-tension which acts all round its edges and pulls the film away from its centre tending to enlarge it. Secondly, the surface of the liquid is necessarily very much curved all round the hole, and a greater pressure is therefore excited at that part by the surface on the liquid which forms the interior of the film than elsewhere. Hence the liquid becomes heaped up around the hole into a ring which is thicker than the rest of the bubble, though its thickness is very small compared with the diameter of the hole. The liquid in the ring is thus in circumstances somewhat similar to that in the long cylinder we have already studied—it undergoes a similar series of transformations and is broken up into drops which are flung away from the bubble. Another ring is instantly formed and as instantly broken, and the process is repeated again and again with inconceivable rapidity, until in a very small fraction of a second a little cloud, composed of the numerous minute drops which have been formed, is all that remains of the bubble.

I must now draw to a close. I have discussed with you, as well as I could in the short space of time allotted to me, the history of a bubble from its birth, in the bosom of the liquid, to its dissolution in the air above. The facts and experiments I have brought to your notice have been, I hope, in themselves sufficient to attract you; but I think they will acquire an additional interest if, before we part, I tell you something about the man to whom we owe most of our knowledge on the subject of my lecture. I mean M. Plateau, the Professor of Physics in the Belgian University of Ghent. This gentleman began his studies on liquids when a young man, and was already well known for his success in scientific investigation, when a misfortune overtook him which one would have thought would have put an end to his further researches. He became hopelessly blind. A misfortune like

this would have crushed a weaker man; but in the case of M. Plateau it served to show the genuine metal he was made of. He spent the long hours of darkness, not in useless repining, or vain regrets, but in endeavoring to advance the knowledge of his race by pondering over the unsolved problems connected with the subjects he understood so well, and in devising experiments, often of the most exquisite ingenuity, for putting his theories and conclusions to the test. These, which he could no longer perform for himself, were undertaken for him by a devoted band of friends, among whom was his own son; and the result has been, not merely a very large addition to our knowledge of the properties of the surfaces of liquids, but, what is perhaps far more important, the presentation to the world of a spectacle of victory over almost overwhelming obstacles such as it has seldom seen. It is not well that our knowledge of scientific facts should be entirely divorced from an acquaintance with the lives and labors of their discoverers, or that we should come to regard them simply as a sort of revelation made to a fortunate few, to the rich inheritance of which we have been lucky enough to succeed. The men who built up the pile of modern science were not of those who sit still and wait with folded hands for some inspiration, they know not whence; rather they performed their tasks, and won success amid difficulties and discouragements to which we in happier times are strangers. But, while rightly ready to pay our homage to the great achievements of the past, we should ever be watchful to honor duly deeds which will cast a lustre upon our own time; and among these the life-work of M. Plateau holds in some respects a position second to none. Others may deserve a higher place for the number, or practical or scientific importance, of their discoveries, but none have more honestly earned the praise due to those who have done what they could; and the world, which is so apt to appropriate the work and forget the worker, should be taught at all events to remember this, that we owe some of the most charming experiments in the whole range of physics to one who himself has never beheld many of them, and of whom, with respect to the rest, we must in all sadness say, he "shall see them again no more forever."

THE EVOLUTION OF HEBREW RELIGION.

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"Dans l'opinion du peuple pour qui ces livres ont été écrits le point capital et essentiel n'est certes pas la narration historique, mais bien la législation et l'édification religieuse."[1]

IN 1795, Frederick Augustus Wolf published a modest octavo volume entitled "Prolegomena to Homer," from whose appearance is dated the beginning of a new era of historic criticism. The composition of the poems of Homer formed its subject. For wellnigh twenty years the author had collected evidence, weighed arguments, and patiently tested his results by constant revision. His own bias was strongly engaged on the side of the unity of the great Grecian epic. But the results of his researches continued to point in the opposite direction, and at last his earnest devotion to truth compelled him to adopt a theory the soundness of whose construction seemed to be no longer questionable. He was thus worthy to become the "founder of the science of philology in its present significance."[2]

The influence of Wolf's discovery was not confined to the study of classic literature only. It quickly radiated through every department of history. "In every singing age," he said, "a single sæculum is almost like a single man. It is all one mind, one soul."[3] This conception involved a new social law, and radically altered the current opinions concerning the relation of individual effort to the larger forces that affect the development of nations. The creative energy of remarkable minds was not, indeed, lessened in importance, but spontaneity, in this connection, acquired a new meaning; and for the *Deus ex machina* of the olden time was substituted the cumulative force of centuries of progressive advancement, culminating, it is true, at last in the triumphant synthesis of genius. The commotion which the Wolfian theory has stirred up in the literary world is largely due to the wide range of ideas which it affected. Yet it was itself but a part of that general movement which, toward the close of the last century, became conspicuous in its effects on every field of human inquiry. Everywhere the shackles of authority were thrown off, and, in place of blindly accepting the testimony of the past, men turned to investigate for themselves. A new principle of research was everywhere acknowledged, a new method was created, and science, natural

[1] "In the estimation of the people for whom these books were written, the capital, essential point surely was, not the historic narrative, but rather legislation and religious edification."—(Nöldeke, "Histoire Littéraire de l'Ancien Testament," p. 19.)

[2] Bonitz, "Ueber den Ursprung der Homerischen Gedichte," p. 11.

[3] In a letter given in Körte's "Leben und Studien F. A. Wolf's," i., p. 307.

and historical, entered upon that astonishing career of discovery whose rich promise for the future we have but begun to anticipate.[1]

To the impetus given by Wolf, and to the new-born spirit of science which he carried into the sphere of philology, we owe among other valuable results the beginnings of a more critical inquiry into the records of ancient Hebrew religion. Indeed, the author of the "Prolegomena" himself clearly foresaw the influence which his book was destined to exert on Hebrew studies. In a letter, from which we have already quoted above, he says: "The demonstration that the Pentateuch is made up of unequal portions, that these are the products of different centuries, and that they were put together shortly after the time of Solomon, may, ere long, be confidently expected. I should myself be willing to undertake such an argument without fear, for nowhere do we find any ancient witness to guarantee the authorship of the Pentateuch to Moses himself."[2]

The prediction embodied in these words soon came true. A host of competent scholars took up the study of the Hebrew Bible, and, profiting by Wolf's example and suggestions, applied to its elucidation the same careful methods, the same scrupulous honesty of interpretation, that had proved so successful in the realm of classical philology. Theologians by profession, they set aside their predilections, and placed the ascertainment of the truth above all other interests. They believed in the indestructible vitality of religion, and were willing to admit the full light of criticism upon the scriptural page, confident that any loss would be temporary only, the gain permanent. In the course of their researches they arrived, among others, at the following important conclusions:

That the editor of the Pentateuch had admitted into his volume several accounts touching the main facts of early Hebrew history; that these accounts are often mutually at variance; that minute analysis and careful comparison alone can lead to an approximately true estimate of their comparative value; and, lastly, that the transmission of historical information had in no wise been the object of the Hebrew writers. The history of their people served, it is true, to illustrate certain of their doctrines concerning the divine government of the world, and especially the peculiar relations of the Deity to the chosen race; but it was employed much in the sense of a moral tale, being designed, not to convey facts, but to enforce lessons. Had the accept-

[1] Scientific pursuits are distinguished from others, not by the material, but by the method of knowledge. The mere collection of data, however multiplied in detail, however abstruse the subjects to which they may refer, does not of itself deserve the name of science. The term properly applies only when phenomena are placed in causal relation, and the laws which govern their development are traced. Measured by this standard, every attempt to explain the growth of human thought and institutions, and to elucidate the laws which have acted in the process of their evolution, has a just claim to be classed under the head of scientific inquiry.

[2] Letter in Körte's "Leben und Studien F. A. Wolf's," i., p. 309.

ance of any particular scheme of Hebrew history been deemed essential to the integrity of religious belief, the Bible, they argued, would certainly not have included discrepant accounts of that history in its pages. In the light of this new insight, it seemed advisable to draw a distinction between the biblical narrative proper and the doctrines which it was designed to illustrate. The latter belong to the province of faith, and their treatment may be left to the expounders of faith. The former is a department of general history, and in dealing with it we are at liberty to apply the same canons of criticism that obtain in every other department, without fearing to trespass upon sacred ground. It is our purpose in the following pages to present some of the more interesting results that have been reached in the study of the Pentateuch, so far as they illustrate the evolution of religious ideas among the Hebrews. We shall begin by summarizing a few instances of discrepant testimony to introduce our subject, and, in particular, to show how little the ordinary purposes of history have been considered in the composition of the biblical writings; how little the bare transmission of facts was an object with the sacred authors.[1]

Scripture opens with two divergent accounts of the creation. In Genesis i., the work of creation proceeds in two grand movements, including the formation of inanimte and animate Nature respectively.[2] On the first day a diffused light is spread out over chaos. Then are made the firmament, the dry earth, the green herbs, and fruit-bearing trees; on the fourth day the great luminaries are called into being; on the fifth, the fishes and birds of the air; on the sixth, the beasts of the field; and, lastly, crowning all, man, his Maker's masterpiece. The human species enters at once upon its existence *as a pair*. "Male and female did he create them." In the second chapter the same methodical arrangement, the same deliberate progress from the lower to the higher forms of being, is not observed. Man, his interests and responsibilities, stand in the foreground of the picture. The trees of the field are not made until after Adam; and, subsequently to them, the cattle and beasts. Moreover, man is a solitary being. A comparison between his lonely condition and the dual existence of the remainder of the animal world leads the Deity to determine upon the creation of woman. A profound slumber then falls upon Adam, a rib is taken from his side, and from it Eve is fashioned.[3] We may notice that the name Jehovah, as appertaining to the Deity, is employed in the second chapter, while it is scrupulously avoided in the first. The

[1] Many of the following examples are familiarly known. A few, however, are drawn from recent investigations. Compare, especially, Kuenen, "The Religion of Israel."

[2] Tuch's "Genesis," p. 3, second edition, Halle, 1871.

[3] For an account of the close analogy between the biblical narration and the Persian story of Meshja and Meshjane, their temptation and fall, *vide* ibid., p. 40. It is of special importance to note that reference to the account of Genesis ii. is made only in the later literature of the Hebrews, ibid., p. 42.

recognition of this distinction has led to further discoveries of far-reaching importance, but too complicated in their nature to be here detailed. The conflicting statements of the two accounts, which we have just indicated, have induced scholars to regard them as the work of different writers. In Genesis iv. we learn that in the days of Enosh, Adam's grandson, men began to call on the name of Jehovah; in Exodus vi., on the contrary, that the name Jehovah was first revealed to Moses, being unknown even to the patriarchs.

Gen. xvi., Hagar is driven from her home by the jealousy of her mistress; escapes into the desert; beholds a vision of God at a well in a wilderness. Gen. xxi., the flight of Hagar is related a second time. The general scheme of the narrative is the same as above; but there are important divergencies of detail. As narrated in chapter xvi., the escape took place immediately before the birth of Ishmael. Fifteen years elapsed,[1] and Ishmael, now approaching the years of maturity, is once more driven forth from the house of Abraham. But, to our surprise, in chapter xxi. the lad is described as a mere infant; he is carried on his mother's shoulders, and laid away, like a helpless babe, under some bushes by the wayside. It appears that we have before us two accounts touching the same event, agreeing in the main incidents of the escape, but showing a disagreement of fifteen years as to the date of its occurrence. The narratives are distinguished as above by the employment of different names of the Deity: Jehovah in the one instance, Elohim in the other.

Gen. xxxii., Jacob at the fords of Jabbok, after wrestling during the night with a divine being, receives the name of Israel. Gen. xxxv., without reference to the previous account, the name Israel is conferred upon Jacob at a different place and under different circumstances.

Gen. xlix., the dispersion of the Levites among the tribes is characterized as a punishment and a curse. They are to be forever homeless and fugitive. Deuteronomy xxxiii. and elsewhere, it is described as a blessing. The Levites have been scattered as good seed over the land. They are the apostles, commissioned to propagate Jehovah's law.

Passing on to the second book of the Pentateuch, we pause before the account of the Revelation on Mount Sinai, beyond a doubt the most important event of Israel's ancient history. Exodus xxiv. 2, Moses alone is to approach the divine presence. Exod. xix. 24, Aaron is to accompany him. Exod. xxiv. 13, Aaron is to remain below and Joshua is to go in his stead. Again, Exod. xxxiii. 20, instant death will overtake him who beholds God. Exod. xxiv. 9–11, Moses, Aaron, two of his sons, and seventy elders of Israel "ascended, and they saw the God of Israel. . . . Also, they saw God, and did eat

[1] Gen. xvii. 25. In quoting from the Old Testament, we follow the order of the Hebrew text.

and drink." Once more, Exod. xxiv. 4–7, Moses himself writes down the words of revelation in a book of covenant. Exod. xxiv. 12, not Moses but God writes them; and, elsewhere, "Two tables of stone inscribed by the finger of God."

Exod. xx. enjoins the observance of the sabbath-day as a memorial of the repose of the Maker of heaven and earth on the sabbath of creation. Deut. v., the fourth commandment is enjoined because of the redemption of Israel from Egyptian bondage. Exod. xxxiv., a new version of the decalogue, differing in most respects from the one commonly received, is promulgated.[1] The first commandment is to worship no strange god; the second, to make no graven images; the third, to observe the feast of unleavened bread; the fourth, to deliver the first-born unto Jehovah; the fifth, to observe the sabbath, etc.

In Exod. xx. we read that the guilt of the fathers will be avenged upon the children down even to the third and fourth generation; in Deut. xxiv., the children shall not die for their fathers. Every one for his own sin shall die.

In Deut. xxv. the marrying of a deceased brother's wife is under certain conditions enjoined as a duty. In Levit. xviii. it is unconditionally prohibited as a crime.

Exod. xxxiii., Moses removes the tabernacle beyond the camp. Num. ii., the tabernacle rests in the very heart of the camp, with all the tribes of Israel grouped round about it, according to their standards and divisions.

Num. xvi., the sons of Korah, the leader of the great Levitical sedition, perish with their father. Num. xxvi., the sons of Korah do not perish.[2]

Of the forty years which the Israelites are said to have dwelt in the desert, not more than two are covered by the events of the narrative. The remainder are wrapped in dense obscurity. There is, however, a significant fact which deserves mention in this connection. The death of Aaron marks, as it were, the close of Israel's journey. Now, while in Num. xxxiii. the death of the high-priest is described as occurring in the fortieth year, in Deut. x. it is actually referred to the second year of the Exodus.[3]

A brief digression beyond the borders of the Pentateuch will show

[1] Compare De Wette's "Einleitung in das alte Testament" (Schrader's edition), p. 286, note 53.

[2] Num. xxvi. 11. Indeed, had the sons of Korah and every human being related to him perished, as Num. xvi. avers, how could we account for the fact that Korah's descendants filled high offices in the Temple at Jerusalem later on? The celebrated singer, Heman, himself was a lineal descendant of Korah. To the descendants of Korah also are ascribed the following Psalms: Ps. xlii., xliv.–xlix., lxxxiv., lxxxv., lxxxvii., lxxxviii.

[3] In connection with this subject it is of interest to compare Goethe's argument on the duration of the desert journey in the "Westöstlicher Divan." Here, as in so many other instances, the intuitive perception of the great poet anticipated the tardy results of subsequent investigation.

that the conflict of testimony which we have thus far noticed, affecting as it does some of the leading events of ancient Hebrew history, does not diminish as we proceed in the narrative. In 1 Samuel vii. it is said that the Philistines ceased to harass the land of Israel all the days of Samuel. Immediately thereupon we read of new Philistine incursions more direful than ever in their consequences.[1] The popular proverb, "Is Saul among the prophets?" is variously explained, 1 Sam. x. and xix. Two discrepant accounts are given of Saul's rejection from the kingdom, 1 Sam. xiii. and xv.; of David's introduction to Saul, 1 Sam. xvi. and xvii. The charming story of David's encounter with the giant Goliath told in 1 Sam. xvii. is contradicted in 2 Sam. xxi. 19, where, not David, but some person otherwise unknown to fame, is reported to have slain the giant Goliath, and also the time, place, and attendant circumstances, are differently related.[2]

It thus appears that the compiler of the Pentateuch has admitted a variety of views, not only on the ancient history of his people, but also on the general subject of religion and morals, into his work; and that the discordant opinions of diverse authors and of diverse stages of human progress are reflected in its pages. It is the monument of a grand religious movement extending over many centuries of gradual development. It is the image of a nation's struggles and growth. As contained in the books of the Pentateuch, the Mosaic religion is a religious mosaic.

In the foregoing sketch we have observed how deep a mist of uncertainty hangs over the earliest period, the golden age of the history of the Hebrews. All is in a state of flux, and what appeared compact and coherent at a distance yields to our touch upon closer contact. To gain *terra firma*, let us turn to the period which immediately succeeded the settlement of the Israelites in Palestine; a period in which the outline of historical events begins to assume a more definite and tangible shape.

It was a dismal and sorrowful age. The bonds of social order were loosened; the current conceptions of the Deity and the rites of his worship were gross and often degrading. Mutual jealousies kindled the firebrand of war among the contending clans. Almost the whole tribe of Benjamin is extirpated. Abimelech slays seventy princes upon one stone. Lust and treachery run riot. A wilder deed has never been chronicled in the annals of mankind than that related in chapter xix. of Judges, nor ever has a terrible deed been more terribly avenged. Now, looking backward, we ask, Is it to be believed that in the fourteenth century B. C. not only the leader of

[1] Compare 1 Sam. vii. 13, and 1 Sam. xiii. 19.

[2] In 1 Chron. xx. 5 we read, "the brother of Goliath." The purpose of the change is clear, and accords well with the apologetical tendencies of the author of Chronicles. *Vide* De Wette, "Einleitung," etc., p. 370. Geiger, "Urschrift."

Israel, but also their elders, their priests, nay, large numbers even of the very populace, shared in the most exalted, the most spiritual conceptions of God, and nourished the most refined sentiments in regard to human relationships, while immediately thereupon, and centuries thereafter, violence, and bloodshed, and idolatry, do not cease from the records? It has been argued, indeed, that the worship of idols was but a *relapse* from the purity of a preceding age; and that, though the tradition of the Mosaic time may have been lost in the succeeding period among the people at large, it was still preserved in the circle of a select few, the judges, King David, and others. These, it is believed, continued to remain faithful disciples of the great lawgiver. But these very men, the judges—King David himself—all fall immeasurably below the standard which is set up in the Pentateuch. If they were esteemed the true representatives of the national religion in their day, if the very points in which they transgressed the provisions of the Mosaic code are distinguished by the approval of God and man, we are forced to conclude that that standard—by which they stand condemned—did not yet exist; that, in the days of David, the laws of Moses, as we now have them, were as yet unwritten and unknown. Let us illustrate this important point by a few examples taken from the records. Gideon no sooner returns from victory than he makes a golden idol and sets it up for worship. Jephthah slays his daughter as an offering of thanksgiving to Jehovah. In the Pentateuch the adoration of images is branded as the gravest of offenses. David keeps household gods in his own home (1 Sam. xix.). In the Pentateuch, on its opening page, God is proclaimed as a pure spirit, maker of heaven and earth. In the eyes of David (1 Sam. xxvi. 19), the sway of Jehovah does not extend beyond the borders of Palestine.[1] In the Pentateuch the ark of the covenant is described as the treasury of all that is brightest and best in the worship of the one God. None but the consecrated priest dare approach it, and even he only under circumstances calculated to inspire peculiar veneration and awe. In 2 Sam. vi., David abandons the ark to the keeping of a heathen Philistine. In an early stage of culture, when fear and terror in the presence of superior force entered largely into the religious conceptions of the Hebrews, the taking of the census was deemed an act of grave transgression. It appeared a vaunting of one's strength; it seemed to indicate a defiant attitude toward the loftier power of the Deity, which he would certainly visit with condign punishment. At a later period the priesthood found it in their interest to override these scruples, and the taking of the census became an affair of habitual occurrence. In the last chapter of Samuel the more primitive view still predominated. Seventy thousand Israelites are miserably slain to atone for King David's presumption in commanding a census of the people. In the fourth book of Moses, on

[1] Banishment being described as a transfer of allegiance to strange gods.

the other hand, the numbering of the people not only proceeds without the slightest evil resulting therefrom, but at the express command of God himself.

In the book of Deuteronomy the service of Jehovah is said to consist mainly in the practice of righteousness, in works of kindness toward our fellows, in sincere and holy love toward the Deity, who is represented as the merciful father of all his human children. 2 Sam. xxi., a famine comes upon the land of Israel. The anger of Jehovah is kindled against the people. To appease him, David offers sacrifice —human sacrifice. The seven sons of Saul are slain, and their bodies kept exposed on the hill, "in the sight of Jehovah," and the horrid offering *is accepted*, and the divine wrath is thereby pacified.[1] Truly, in the age of David, the Hebrews were far, far removed from that high state of culture in which the ideal conception of religion that pervades Deuteronomy became possible. And long after, when centuries had gone by and the kingdom of Judah was already approaching its dissolution, the direful practices of David's reign still survived, and the root of idolatry had not been plucked from the heart of the people. Still do we hear of human sacrifice perpetrated in the midst of Jerusalem, and steeds and chariots dedicated to the sun-god, and images of the Phallus, and all the abominations of sensual worship, filled the very Temple of Jehovah.

But in the mean time a new force had entered the current of Hebrew history. The conviction that one God, and he an all-just, almighty being, rules the destinies of Israel, began to take root. In the eighth century B. C. authentic records prove that monotheism, as a form of religious belief, obtained, at least among the more illustrious members of the prophetic order. We have elsewhere attempted to trace the causes which led to the rise of monotheism at this particular epoch, and shall do no more than briefly allude to them here.

When the mountaineers of Southern Palestine, after centuries of protracted struggle, had secured the safe possession of individual homes, the endearments of domestic life were invested with a sanctity in their eyes never before known. The attachment of the Hebrew toward his offspring was intensified; his devotion to the wife of his bosom became purer and more enduring. Now, the prevailing forms of Semitic religion outraged these feelings at every point. The gods of the surrounding nations were gods of pleasure and of pain; and in their worship the stern practices of fanatic asceticism alternated with the wildest orgies of sensual enjoyment. The worship of Baal Moloch demanded the sacrifice of children; that of the lascivious Baaltis in-

[1] It is important to note that the seven sons of Saul were sacrificed in the beginning of the barley-harvest. This circumstance seems to throw light on the primitive mode of celebrating the Passover. That the rite of human sacrifice was originally connected with this festival is generally acknowledged. *Vide*, e. g., Exod. xiii., 2. By such offerings it was intended, no doubt, to secure the favor of the god during the continuance of the harvest.

sulted the modesty of woman. The nobler spirits among the Hebrews rebelled against both these demands. And, as they were put forth in the name of the dominant religion, the inevitable conclusion followed that that religion itself must be radically wrong. The spirit of opposition thus awakened was aroused into powerful activity when, in the days of Ahab, the queen, supported by an influential priesthood, determined to introduce the forms of Phœnician religion in Israel by measures of force. The royal edicts were resisted, but for a while the rule of the stronger prevailed. The leaders of the opposition were compelled to flee, and, avoiding the habitations of men, to take refuge in wild and solitary places. Thus the rupture was widened into schism, and persecution inflamed the zeal and kindled the energies of that new order of men of whom Elijah is the well-known type.

Through their agency the emotional nature of the Semitic race now found expression in a form of religious worship loftier by far than any that had ever arisen among men. If Baal was the embodiment of Semitic asceticism and Baaltis the type of sensual orgiastic passion, the national God of Israel now became the type of a nobler emotion, the guardian of domestic purity, the source of sanctity, the ideal Father. It is, indeed, the image of a just patriarch that fills the mind and wings the fancy of the eldest prophets, when they describe the nature of Jehovah, their God. Jehovah is the husband of the people. Israel shall be his true and loyal spouse. The children of Israel are his children. Unchastity and irreligion are synonymous terms. And thus, if we err not, the peculiar feature of Hebrew character, their faithful attachment to kith and kin, the strength and purity of their domestic affections, serves to explain the peculiar character, the origin and development of the Hebrew religion. And because the essential elements of the new religion were moral elements it could not tolerate the Nature-worship of the heathens; and the way was prepared for the gradual ascendency of the purely spiritual in religion, which after ages of gradual progress constituted the last, the lasting triumph of prophecy.

After ages of development! For we are not to suppose that, in the centuries succeeding Hosea, the doctrines of the prophetic schools had become in any sense the property of the people at large. "The powers that be" were arrayed against them, and the annals of the kings are replete with evidence of their sufferings. It was in the late reign of Josiah that they at last received not only the countenance of the reigning monarch, but also a decisive influence upon the direction of affairs. In that reign a scroll was found in the temple imbued with the doctrine of the unity of God, and breathing the vigorous spirit of the prophets. In it was emphasized the heart's religion in preference to the empty ceremonial of priestly worship. The allegiance of the people was directed toward the God who had elected them from among the nations of the earth, and dire disaster was pre-

dicted in case of disobedience. When brought to the king and read in his presence, he was powerfully affected, and determined, if possible, to stem the tide of impending ruin by such salutary measures of reform as the injunctions of the newly-found Scripture seemed most urgently to call for. The concurrence of many critics has identified this scroll, written and published at or about the time when the youthful Josiah succeeded to the throne of his ancestors, with Deuteronomy, the fifth of the books of Moses. It differs materially from the more recent writings of the Pentateuch. The family of Aaron are not yet exclusively endowed with the priesthood. The priests are all Levites, the Levites all priests. There are, moreover, other vital differences, into which the limits of this article do not permit us to enter.[1] The date of the composition of Deuteronomy is thus referred to the closing decades of the seventh century B. C.[2]

The princes who succeeded Josiah fell back into the old course, and quite undid the work which had begun with such fair promise. Indeed, little permanent good was to be hoped for in so disordered a condition of political affairs, and from the degenerate rulers who then swayed the helm of state. The fortunes of the kingdom of Judah were swiftly declining, and, but a quarter of a century after the pious Josiah had breathed his last, Nebuchadnezzar burned the Temple of Jerusalem, and carried its inhabitants captive to Babylon.

Heretofore, with but a brief, brilliant interlude, idolatry had been the court religion of Judah. Early training, long usage, the example of revered ancestors, had endeared its forms and symbols to the affections of the people. Resistance to the innovating prophets was natural; men being then, as ever, loath to abandon the sacred usages which had come down to them from the distant generations of the past. But, in the long years of the captivity, a profound change came over the spirit of the Hebrew people; "by Babel's streams they sat and wept;" by Babel's streams they recalled the memories of their native land, that land which they had lost. It was then that the voices of Jehovah's messengers, which had so earnestly warned them of the approaching doom, recurred to their startled recollection. They remembered the message; they beheld its fulfillment; the testimony of the prophets had been confirmed by events; the one God to whom they testified had revealed his omnipotence in history; and with willing assent the exiles promised allegiance to his commandments in the future. The love of country, the dread of further chastisement, the dear hope of restoration, combined to win them to the purer worship of their God, and, in the crucible of Babylon, the national religion was purged of the last dregs of heathendom.

[1] E. g., the rebellion of Korah is unknown to the author of Deuteronomy.

[2] The language of Deuteronomy attests its late origin. Sixty-six phrases of Deuteronomy recur in the writings of Jeremiah. *Vide* Zunz, *Zeitschrift der Deutschen Morgenländischen Gesellschaft*, xxviii., p. 670.

With the permission of Cyrus, the Jews returned to Palestine, and the Temple at Jerusalem was rebuilt. The question now arose in what forms the ceremonial of the new sanctuary should be conducted. The time-honored festivals, the solemn and joyful convocations, the sacrifices and purifications of the olden time, were all more or less infected with the taint of paganism. Prophecy would have none of them—prophecy, free child of genius, contemned sacrifice, denounced the priesthood, even the temple and its ritual;[1] proclaimed humbleness and loving-kindness as the true service in which Jehovah takes delight. There was formalism on the one hand, idealism on the other. As is usual in such cases, when the time had arrived for turning theory into practice, it was found necessary to effect a compromise. As Christianity in later days adopted the yule-tree into its system, and lit the lamps of the heathen festival of the 25th of December in honor of the nativity of its founder, so the leaders of the Jews, in the fifth century before our era, adopted the feasts and usages of an ancient Nature-worship, breathed into them a new spirit, informed them with a loftier meaning, and made them tokens, symbols of the eternal God. The old foes were thus reconciled; priesthood and prophecy joined hands, and were thenceforth united. As an offspring of this union, we behold a new code of laws and prescriptions, whose marked and inharmonious features at once betray the dual nature of its progenitors. "A rough preliminary draft, as it were," of this code, is preserved in the book of Ezekiel, composed probably about the middle of the fifth century. In its finished and final shape, it forms the bulk of a still later work—of Leviticus, the third of the books of the Pentateuch: of all the discoveries of criticism, none more noteworthy, none we are bound to consider more assured. What lends additional certainty to the result is the circumstance that it was reached independently by two of the most esteemed scholars of our day, the one a Professor of Theology in the University of Leyden,[2] the other a veteran of thought, whose brow is wreathed by the ripe honors of more than fourscore years.[3] Let us briefly advert to the line of argument by which this astonishing conclusion was reached:

The author of the book of Ezekiel was a priest, and one confessedly loyal to the sanctuary of Jerusalem. Now, had the laws of the Levitical code, which minutely describe the ritual of that sanctuary, existed, or been regarded as authoritative in his day, he could not, would not have disregarded, much less contradicted, their provisions. He does this, and, be it remarked, in points of capital importance. In chapter xlv. of Ezekiel are mentioned the great festivals, with the sacrifices appropriate to each; but the feast of Pentecost, commanded in Leviticus, is entirely omitted; also that of the eighth day of tabernacles. The second of the daily burnt-offerings, upon which the legislator of

[1] Jeremiah vii. 4; Isaiah lxvi. 1; Micah vi. 6.

[2] Prof. A. Kuenen.

[3] The venerable Dr. Zunz, of Berlin.

the fourth book of Moses dwells with such marked emphasis, is not commanded. The order of sacrifices appointed in Ezekiel is at variance with that in the more recent code. Ezekiel nowhere mentions the ark of the covenant. According to him, the new year begins on the tenth of the seventh month, while the festival of the trumpets, ordained in Leviticus for the first of that month (the present new year of the Jews), is nowhere referred to. We are not to suppose, however, that the festivals, the ark, etc., did not yet exist in the time of Ezekiel. They existed, no doubt, but were still too intimately associated with pagan customs and superstitions to receive or merit the countenance of a prophetic writer. In Leviticus the process of assimilation above described had reached its climax. The new meaning had been successfully engrafted upon the rites and symbols of the olden time; and they were thenceforth freely employed. The legislation of the Levitical code exhibits the familiar features which in every instance mark the ascendency or consolidation of the hierarchical order. The lines of gradation and distinction between the members of the order among themselves are precisely drawn and strictly adhered to. The prerogatives of the whole order as against the people are fenced about with stringent laws. The revenues of the order are largely increased. In the older code of Deuteronomy, the annual tithes were set apart for a festival occasion, and given over to the enjoyment of the people. In the new code, the hierarchy claims the tithes for its own use. New taxes are invented. The best portions of the sacrificial animal are reserved for the banquets of the Temple. The first-born of men and cattle belong to the priesthood, and must be ransomed by the payment of a sum of money. In no period prior to the fifth century B. C. was the hierarchy powerful enough to design such laws. At that time, however, when in the absence of a temporal sovereign they, with the high-priest at their head, were the acknowledged rulers of the state, they were both prepared to conceive and able to carry them into effect. The language of Leviticus contributes not a little to betray its late origin.[1] The authorship of Moses attributed to the Levitical code is symbolical. *The name of Moses is utterly unknown to the elder prophets.* In all their manifold writings it does not occur a single time, though they make frequent reference to the past. There can now be little doubt that the composition of the bulk of Leviticus, and of considerable portions of the books of Numbers, Exodus, and even parts of Genesis, belongs to the epoch of the second Temple, and that the date of these writings may be approximately fixed at about one thousand years after the time of Moses. As to the story of Israel's desert wanderings, it rests upon ancient traditions

[1] To mention only a single instance, ha Shem (meaning the name, i. e., the ineffable name of God) was not employed until a very late period in the history of the Jews, when the fear of taking the name of the Lord in vain induced men to avoid, if possible, mentioning it at all. We find ha Shem in the above sense in Lev. xxiv. 11.

whose character it is not our present business to investigate. It was successively worked up in various schools of priests and prophets, and this accounts for the host of discrepancies it contains, some of which have been noticed in the beginning of this essay. It was finally amplified by the inventive genius of the second-Temple priesthood, who succeeded in heightening the sanctity of their own institutions by tracing them back to a revered, heroic person, who had lived in the dim days of remote antiquity.

In the preceding pages we have indicated the more important phases of that great conflict which ended in the establishment of monotheism, whose traces, though sometimes barely legible, are still preserved in our records. We saw in the first instance that the Mosaic age is shrouded in uncertainty. We pointed out that pure monotheism was unknown in the time of the early kings. We briefly referred to the rise of monotheism. Finally, we endeavored to show how the prophetic idea had been successively expressed in various codes, each corresponding to a certain stage in the great process of evolution. From what we have said, it follows that the prophetic ideal of religion is the root and core of all that is valuable in the Hebrew Bible. The laws, rites, and observances, in which it found a temporary and changeful expression, may lose their vitality; it will always continue to exert its high influence. It was not the work of one man, nor of a single age, but was reached in the long course of generations on generations, evolved amid error and vice, slowly, and against all the odds of time. It has been said that the Bible is opposed to the theory of evolution. The Bible itself is a prominent example of evolution in history. It is not homogeneous in all its parts. There are portions filled with tales of human error and fallibility. These are the incipient stages of an early age—the dark and dread beginnings. There are others thrilling with noblest emotion, freighted with eternal truths, breathing celestial music. These are the triumph and the fruition of a later day. It is thus by discriminating between what is essentially excellent and what is comparatively valueless that we shall best reconcile the discordant claims of reason and of faith. The Bible was never designed to convey scientific information, nor was it intended to serve as a text-book of history. In its ethical teachings lies its true significance. On them it may fairly rest its claims to the immortal reverence of mankind.

There was a time in the olden days of Greece when it was demanded that the poems of Homer should be removed from the schools, lest the minds of the young might be poisoned by the weeds of superstitious belief. Plato, the poet-philosopher, it was who urged this demand. That time is past. The tales of the gods and heroes have long since ceased to entice our credulity. The story of Achilles's wrath and the wanderings of the sage Ulysses are not believed as history, but the beauty and freshness and the golden poetry of the

Homeric epic have a reality all their own, and are a delight and a glory now, as they have ever been before. The Bible also is a classical book. It is the classical book of noble ethical sentiment. In it the mortal fear, the overflowing hope, the quivering longings of the human soul toward the better and the best, have found their first, their freshest, their fittest utterance. In this respect it can never be superseded.

To Greek philosophy we owe the evolution of the logical categories; to Hebrew prophecy, the pure canon of moral principle and action. That this result was the outcome of a long process of suffering and struggle cannot diminish its value in our estimation. When we compare the degrading offices of the Hebrew religion in the days of the judges with the lofty aspirations of the second Isaiah, when we remember the utter abyss of moral abasement from which the nobler spirits of the Hebrews rose to the free summits of prophecy, our confidence in the divine possibilities of the human soul is reinvigorated, our emulation is kindled, and from the great things already accomplished we gather the cheering promise of the greater things that are yet to come. It is in this moral incentive that the practical value of the evolutionary theory chiefly lies.[1]

PRESENT STATUS OF SOCIAL SCIENCE—REPLY TO A CRITIC.

By ROBERT S. HAMILTON.

WHEN a periodical of such wide circulation and deservedly high reputation as THE POPULAR SCIENCE MONTHLY disparages an author by its criticism, silence on his part might reasonably be construed into acquiescence in its justness. It is, therefore, hoped that this reply to a criticism on the late work, published by H. L. Hinton & Co., on "The Present Status of Social Science," which appeared in that monthly for May, 1874, will not be denied a place in the same columns that allowed the criticism.

The main accusation preferred against the book—and it is almost the only one—is, that it is "an old book," and of "an antiquated character."

It may not be out of place here to remind our critic that some of the

[1] Most aptly has this thought been expressed in the lines with which Goethe welcomed the appearance of F. A. Wolf's "Prolegomena:"

> "Erst die Gesundheit des Mannes, der, endlich vom Namen Homeros
> Kühn uns befreiend, uns auch führt in die vollere Bahn.
> Denn wer wagte mit Göttern den Kampf? und wer mit dem Einen?—
> Doch Homeride zu seyn, auch nur als letzter, ist schön."
>
> *The Elegy of Hermann und Dorothea.*

oldest books in the world are among the most valuable, that age does not necessarily detract from the real merit of a book, or of any truth it may advocate, any more than it does from the quality of wine, or of ancient, long-tried, long-approved friendship, *that an old truth is even better than a new error*, and that one of the highest and most important functions of the philosopher, in every age, is to reconcile the new with the old, to harmonize the latest revelations of science with the venerable traditions and immutable ideas of the race; in short, to keep mankind constant, and bring them back to the *old landmarks*, the primary and fundamental truths, from which they have a constant tendency to wander off and go astray. Perhaps it might not be amiss, furthermore, to remind him that the present age, more than any other, and especially this department of science, require to be admonished with the warning proverb of Solomon, "Remove not the ancient landmarks which thy fathers have set."

But with what propriety can a book be called old, or antiquated in character, that deals almost exclusively, and that, too, with almost unqualified approbation and accord, with the views of such recent and highly-advanced thinkers as Guizot and Hallam, Sismondi and Mill, Cousin, Buckle, Comte, and Herbert Spencer?

If the book in question is old, all that Herbert Spencer has written on sociology is likewise old. If there is nothing new in this book, there is nothing new in any of the reasonings, on society, of that Magnus Apollo, we might almost say, that *alter ego*, of THE POPULAR SCIENCE MONTHLY. We challenge our critic to produce a single idea of Herbert Spencer's, having any important bearing on the philosophy of society, and any claim to be considered at all new, either in his "Social Statics," or any other of his works, that is not contained in the "Present Status of Social Science," either in direct expression, or in fair, direct, and inevitable logical sequence, from what is directly expressed. Will our critic accept the challenge, with the privilege of only a brief reply accorded to a misrepresented and much-wronged author? We hardly think so.

The truth rather seems to be, that the work in question contains rather too much about Mr. Spencer and his philosophy of society. It contains, *substantially*, not only all that is true or essentially valuable in the suggestions of that great and eminently valuable thinker, up to the present time, but something that is not so valuable or true. It contains, in short, a rather too caustic, possibly too just, and unanswerable criticism on his extreme and exaggerated applications of the *laissez-faire* doctrine, and upon his fantastical reasonings about "the evanescence of evil." It takes too just exceptions to his condemnation of any and all provision, by the state, for the relief of the poor, or even for their education.

But the plea of our critic, which is plausible only on its face, is, that it was unfair, unjust, thus to attack Mr. Spencer, when his views

had not as yet been fully presented to the world. On this point, which is the main point, he says: "An example of the antiquated and unreliable character of the work is afforded by the author's treatment of the most eminent thinker of the times on problems of social science. Mr. Herbert Spencer is judged as a sociologist by his views developed in 'Social Statics;' how justly will appear from the fact that 'Social Statics' was Mr. Spencer's first work, published twenty-four years ago. And not only this, but he was so dissatisfied with it that he would not consent to its republication in this country without incorporating a preface, which indicated that his views had undergone important modifications."

Now, what does our critic mean by the equivocal expression, "Mr. Spencer is judged," etc., "by his views expressed in 'Social Statics?'" Does he mean that he has been judged in part, or altogether and solely, by his "Social Statics?" If the former only, what is the ground of complaint? What more fair, or just, than that an author should be judged, in part, by a part of his performance, by one of his most formal and elaborate works? If he means the latter, then he is greatly mistaken, and grossly misrepresents the author. Mr. Spencer is judged in the work in question, not only by his "Social Statics," but by his brilliant article on "The Social Organism," to be found in his "Illustrations of Universal Progress," by his truly great work on "First Principles," in which are contained some of his most valuable thoughts on sociology,[1] and to some and not unimportant extent, also, by his "Principles of Biology," and other writings.

And now to the main point of the criticism, its very citadel, which, briefly rendered, is, that Mr. Spencer has been judged, at least to a very large and important extent, by a work which he has virtually retracted or disclaimed, in some of its essential doctrines. On this point, as will be seen, the critic expresses himself with a very cautious reserve, gently insinuating, merely, what he could hardly venture directly to assert. In reference to the preface, which Mr. Spencer insisted on incorporating with the republication of the "Social Statics," in this country, he says it "indicated that his views had undergone important modifications."

Now, we must beg leave, most respectfully but most emphatically, to dissent from the critic's interpretation of Mr. Spencer's preface in question, and to say that it indicated, very clearly, that his views had undergone only *some slight and unimportant modifications*. The precise words of Mr. Spencer's preface, on this point, are "some accompanying modifications." But the whole context conclusively demonstrates that "those modifications" were not important, not material, in respect to the essential or substantial import of his ideas.

He begins his preface by saying he would not have the American public to take this work as "a literal expression" of his present

[1] *See* "Present Status," etc., pp. 126–128, or chapter vi., § 12.

views. He proceeds to say that now, after the lapse of fourteen years, were he writing out his thoughts on the subject, he would express himself somewhat differently on several specified points. Then by way of excusing himself from rewriting his views, and of showing the little importance of his doing so, he concludes his preface with these conclusive words, expressing himself in the third person: "When, however, he comes to the closing volumes of this system, should he ever get so far, he proposes to set forth in them the developed conclusions of which 'Social Statics' must be considered a rough sketch." What more conclusive proof could we need that "Social Statics" was still, then and there, a *substantial* embodiment of his views?

The critic says that the author of the work in question appears to have "an obscure conception of social science," etc. It is to be remembered, however, that social science is a very large science, susceptible of very diverse renditions, or modes of consideration, and that, when viewed, as it is by Mr. Spencer and his especial admirers, from the lofty standpoint of universal science, it would be likely to present somewhat different points of prominence for scientific consideration from those it would present from the far less ambitious standpoint from which it is viewed by the author in question—the standpoint of the practical statesman and jurist.

By way of illustrating the fairness and justness of his criticism, the critic quotes an isolated passage from the work under his consideration, which, unexplained, and rent from its context, would appear only as Greek, Hebrew, or Sanscrit, to the general reader; a passage in which, after the example of Mr. Spencer himself, and other modern scientists, the author had casually drawn on astronomical science for illustration, and instituted a similitude between the forces of cosmical and social life. But was that a really fair selection? What would our critic think if any one should undertake to judge Mr. Spencer, either as a sociologist or a general scientist, solely by his fundamental postulate that all evolution is from the *homogeneous* to the *heterogeneous*?

The critic would have conveyed to his readers a far more just idea of the scope and real character of the work under his review—a mere preliminary work as it is—if he had seen fit to quote the *seven propositions* laid down in the author's sixth chapter, embodying, as they claim to do, the essential import of all the most recent and most advanced thought in social philosophy; nay, embodying, in outline, the very quintessence of Mr. Spencer's peculiar views, with the addition of only a few highly-important ideas, which he seems to have either overlooked or undervalued.

And here it may be proper to remark that there is no essential antagonism between Mr. Spencer and the author who has incurred the displeasure of THE POPULAR SCIENCE MONTHLY. On fundamental principles, and in the general drift of their reasonings, likewise, they

are in almost perfect accord—co-laborers in the same great field—endeavoring to compass it only by different methods.

While Mr. Spencer is tugging at the vast problems of social science from the standpoint of the universal scientist, the author in question is viewing them more directly from the standpoint of the specialist in *sociology*—and more particularly in the department of *statesmanship*—seeking and deriving valuable instruction from the vast generalizations of his more able and far more learned co-laborer.

Can it be supposed, however, that the two laborers will not differ, somewhat, in some of their practical applications of the very same general principles which they hold in common? Or need it be wondered at that, while Mr. Spencer would abolish the state school and state provision for the poor, the author in question would rather remodel and enlarge the scope of both, while admitting and appreciating the great abuses and mischiefs that may result from either?

Does not the very loftiness of Mr. Spencer's standpoint, the grandeur of his views, and the vast and far-reaching comprehensiveness of his observations, make it impossible, despite his great and indisputable sagacity, to avoid some mistakes in respect to the great practical problems of social life, and to escape altogether the error, so common with our modern reformers, of seeking to abolish institutions that need only amendment and reform?

In conclusion, let the hope be expressed that "the antiquated character" of this reply will find excuse in the fact that, although the privilege of making it was solicited early in June, 1874, it was not accorded until late in October following, when the author, in despair of obtaining justice, or a fair hearing, at least in this country, had abandoned all idea of replying. Weeks and even months then elapsed before the purpose of doing so revived in his mind, under the conviction that such a course was due, not only to himself, but to the momentous theme, which he has made the theme of his life, and on which he feels a strong assurance that he has some suggestions to offer, some great universal truths, *great fundamental laws of social life*, to announce, that are calculated to exert an important influence on the cause of knowledge and human advancement.

CINCINNATI, *February* 22, 1875.

SKETCH OF PROF. WILLIAM B. ROGERS.

THE President of the American Association for the Advancement of Science, who presides at its meeting this year in Buffalo, belongs to a family which has attained eminent distinction in the field of American science. He was born in Philadelphia, in December, 1805, and is the second of four sons—James Blythe, WILLIAM BAR-

TON, Henry Darwin, and Robert Empeie Rogers, all of whom have won celebrity as scientific teachers and investigators, and of whom William and Robert alone survive.

Their father, Patrick Kerr Rogers, was a man of varied attainments, and an enthusiastic student and teacher of natural science, who, besides lecturing to medical classes, was among the first in this country to establish systematic courses of instruction in chemistry and experimental physics for the general public. His sons were educated chiefly at home under his immediate care, the elder continuing their studies at William and Mary College, their father having been appointed Professor of Natural Philosophy and Chemistry in that institution.

When twenty-one years of age, William gave his first lectures on science in the Maryland Institute, Baltimore, and the following year was appointed to succeed his father in William and Mary College, where he remained until 1835. He was then appointed to the chair of Natural Philosophy in the University of Virginia, and there extended his instructions by adding the subjects mineralogy and geology to his course. The same year he organized the geological survey of the State, having, while a professor at William and Mary, begun his geological labors with an examination of the Tertiary region, of which he published, in conjunction with his brother, Henry D. Rogers, two memoirs in the "Transactions of the American Philosophical Society." At this time, besides other chemical researches, he made an analysis of the waters of the Virginia mineral springs, the results of which have appeared in various publications.

He remained at the head of the geological survey until it was discontinued in 1842, having published a series of annual reports and collected further materials, for the completion and publication of which, however, no provision was made by the State. While at the university he published for the use of his students a short treatise on the "Strength of Materials" (Charlottesville, 1838), and a volume on "The Elements of Mechanical Philosophy" (Boston, 1852). During this period of his life, besides the cares of his professorship and of the survey, he occupied himself with original researches in various departments of science, partly geological, in connection with his field-work, and, after the survey ended, chiefly in chemistry and physics.

In 1840 the "Association of American Geologists and Naturalists" was organized. In this society, embracing Hitchcock, Hale, Vanuxem, the four brothers Rogers, Conrad, Emmons, and others, engaged in active scientific research, Prof. Rogers took a leading part, as will be seen by referring to the volume of its "Transactions" (1840–'42), to which he contributed among other articles the following memoirs: "On the Age of the Coal-Rocks of Eastern Virginia;" "On the Connection of Thermal Springs with Anticlinal Axes and Faults;" "Observations of Subterranean Temperature in the Coal-

Mines of Eastern Virginia;" and "On the Physical Structure of the Appalachian Chain," etc. In the first of these papers Prof. Rogers showed that the formation in question, instead of being of an age anterior to the Carboniferous, as had been maintained by Maclure and R. C. Taylor, was of Mesozoic time. In the second paper he described the position of more than fifty thermal springs in the Appalachian belt, occurring in an area of about 15,000 square miles, deducing the law that these thermal springs issue from anticlinal axes and faults, or from points very near such lines, and, in connection with their chemistry, proving the important fact of the great preponderance of nitrogen in the free and combined gases of these springs. The observations on subterranean temperature recorded in the third paper were the first published confirmation, as regards the United States, of the law of augmenting temperature beneath the surface of the earth, although similar observations had been made by Humboldt in Mexico. The memoir on the physical structure of the Appalachian chain, etc., was the joint work of Profs. W. B. and H. D. Rogers, founded on their explorations of this belt in Pennsylvania and Virginia, and its prolongation toward the southwest and northeast. The novelty and importance of its generalizations were at once recognized in Europe as well as at home, and gave the authors, "the Gebrüder Rogers," a prominent place among contemporary geologists; and, so far as the development of the physical structure of the Appalachians is concerned, this memoir is still regarded as of classical value.

Prof. Rogers was chairman of the Association in 1845, and again two years later, when it was expanded into the "American Association for the Advancement of Science," at the first meeting of which he presided until it was fully organized.

In connection with his brother, Robert E. Rogers, now become his colleague as Professor of Chemistry and Materia Medica in the university, he published a number of important chemical contributions, relating chiefly to new or improved methods in chemical analysis and research, in *Silliman's Journal*, between 1840 and 1850. Among these were papers "On a New Process for obtaining Pure Chlorine;" "A New Process for obtaining Formic Acid, Aldehyde, etc.;" "On the Oxidation of the Diamond in the Liquid Way;" "On New Instruments and Processes for the Analysis of the Carbonates;" "On the Absorption of Carbonic Acid by Liquids," an extended investigation; and "On the Decomposition of Rocks by Carbonated and Meteoric Waters," a paper of much interest in its geological bearings.

In the volume of the "Transactions of the British Association" for 1849, Prof. Rogers called attention to the existence of true coal-measures below the horizon of the Carboniferous limestone in the Appalachian belt as discovered by him in the Virginia survey, and referred to in his annual reports.

He married, in 1849, a daughter of Hon. James Savage, of Boston, President of the Massachusetts Historical Society, and author of the "Genealogical Dictionary," and in 1873 removed to that city, where he has since resided. Here, although he early identified himself with the educational and public interests of the community, he did not relax his devotion to scientific labors, which were now, however, more largely directed to the department of experimental physics. Among his contributions to physics at this period may be mentioned a series of papers "On Binocular Vision, giving an Elaborate Analysis of the Phenomena, with some Important Additions to the Researches on this Subject of Wheatstone and Brewster;" "Experiments on Sonorous Flames," in which he described an apparatus for making visible the vibrations by rotating the flame; and "On the Formation of Rings of Air and Liquids"—all of which may be found in *Silliman's Journal* (1855–'60).

He also published, in the *New Edinburgh Philosophical Journal*, the results of continued observations on atmospheric ozone, and on the auroras of August and September, 1859 and 1860. As a member of the American Academy of Arts and Sciences, and of the Boston Society of Natural History, of the former of which he was for many years the corresponding secretary, Prof. Rogers took an active part in the discussions of the various scientific questions then rising into importance, and made contributions from time to time to their published proceedings. Among the communications to the American Academy we may note papers "On the Protozoic Age of Certain Rocks in Eastern Massachusetts;" "On the Actinism of the Electric Discharge in Vacuum Tubes," of which he exhibited numerous photographs, in connection with his paper on the improvements, by Mr. E. S. Ritchie, of the Ruhmkorff apparatus; and "Experiments disproving, by the Binocular Combination of Visual Spectra, Brewster's Theory of Successive Combination of Corresponding Points."

In the "Transactions of the Boston Society of Natural History" appeared, among other articles by Prof. Rogers, communications "On the Growth of Stalactites;" "Geological Relations of the New Red Sandstone of the Middle States to the Coal-Rocks of Eastern Virginia and North Carolina;" "On the Origin and Accumulation of the Protocarbonate of Iron in Coal-Measures;" "On the Natural Coke and Associated Igneous Rocks of Eastern Virginia;" and "On Pebbles in the Newport Conglomerate."

At the annual meetings of the American Association for the Advancement of Science, Prof. Rogers has been a frequent contributor, as well in the discussions of scientific questions as in the communication of original papers, which, however, in most cases, appear only by title in their "Transactions," or are to be found in other publications before mentioned.

In 1853 he removed to Boston, where he has since resided. At

the request of his friend Governor Andrew, in 1861, he accepted the office of Inspector of Gas and Gas-Meters for the State of Massachusetts, and organized a system of inspection in which he aimed to apply scientific principles more fully than had hitherto been attempted in the United States. Some account of his methods was given at a meeting of the British Association. During this time Prof. Rogers was often called upon for public lectures on scientific subjects in Massachusetts and elsewhere, and gave several courses before the Lowell Institute in Boston.

Prof. Rogers had long felt the need, in our educational system, of giving to the physical sciences a higher place and more practical methods of teaching than had hitherto been allowed them, and he was therefore eager to avail himself of the opportunity for carrying out these views. In behalf of a committee of gentlemen who had become interested in the subject, he drew up a scheme entitled "Object and Plan of an Institute of Technology," embracing a society of arts, a museum of arts, and a school of industrial science; and he subsequently addressed a memorial to the Legislature of Massachusetts, urging the establishment of such an institution. After some delay a charter for the "Institute of Technology" was granted, and Prof. Rogers was placed at its head. A whole square of land on Back Bay was granted for building-purposes—one third to the Boston Society of Natural History, the other two thirds to the Institute of Technology. But the popularity and increasing prosperity of the Institute make it already cramped in its present stately hall, and it will soon be necessary to have another edifice. The detailed plan for the departments of the school, prepared by Prof. Rogers in 1864, has been carried out, with but slight modifications. A marked feature of this plan, which has since been adopted in many other institutions, was the introduction of laboratory teaching, not only in the department of chemistry, but in that of physics, mechanics, and mining, a feature which has no doubt contributed largely to the reputation which the school has acquired for thoroughness of scientific training.

Besides being president of the Institute, Prof. Rogers filled the chair of Physics and Geology for several years after the establishment of the school. It may be added that he was active in founding the American Social Science Association, and was its first president.

But this inventory of the life-work of Prof. Rogers, extensive and interesting as it is, leaves out a powerful element of the influence he has exerted as a teacher over great numbers of young men who have been brought within the spell of his personality. Prof. Rogers is an orator of the first class, and we have long regarded him as the most impressive and delightful speaker that has appeared before the American Association. And it must be remembered that science puts oratory to its highest test; it is a field in which reason is supreme, and where the speaker is not at liberty to throw logic to

the winds, and make his fiery appeal to the feelings and passions of listeners. The scientific orator must address intelligent men, habituated to think for themselves, on the alert against tricks that carry the imagination, while the speaker himself is kept under the close restraints of fact. To be able to captivate and enchain an audience in the pure work of exposition, to fascinate in teaching, is a triumph of oratorical art. Prof. Rogers has been marked by the possession of this rare gift, and before his classes in college, whether treating of rocks, physical forces, or rigid principles of mathematics, he was always able to kindle the enthusiasm of the students, and make the most vivid and lasting impressions upon their minds. We were not surprised, therefore, to note, in a Virginia newspaper of last year, an exciting description of the way Prof. Rogers was received by his old students at the semi-centennial of the University of Virginia, where he "was the central object, on whom were fixed the eyes and hearts of the great concourse there assembled from all parts of the country. It was difficult to get near enough to speak to him, surrounded as he was by such numbers of those who in years long past had attended his lectures." He made an address, the reception of which is described by the writer with a pardonable warmth: "At the dinner of the alumni, Prof. Rogers addressed them in a speech of half an hour. It was a wonderful specimen of eloquence. The old students beheld before them the same William B. Rogers who, thirty-five years before, had held them spellbound in his class of natural philosophy; and as the great orator warmed up, these men forgot their age; they were again young, and showed their enthusiasm as wildly as when in days of yore, enraptured by his eloquence, they made the lecture-room of the university ring with their applause. Such was the effect produced by the off-hand words of this distinguished man of science and unrivaled orator; and those who have heard him in his moments of inspiration will not wonder at the account we have given."

Some time ago failing health compelled Prof. Rogers to retire from the active direction of the Institute. He still, however, has a share in its government, and his returning strength for the last two or three years has enabled him gradually to resume his favorite pursuits.

CORRESPONDENCE.

A STONE BATTLE-AXE.

To the Editor of the Popular Science Monthly:

I HEREIN give you the outlines of a large-sized battle-axe, found in a thick bed of drift on the elevated surface of Rose or Cemetery Hill, Cumberland, Maryland. This locality is situated on the first plateau at the base of Will's Mountain, on the south side of Will's Creek, and east side of the mountain, and within the limits of the city of Cumberland.

The unassorted drift that spreads over this plateau for miles, and which lies about two hundred and fifty feet above the bed of

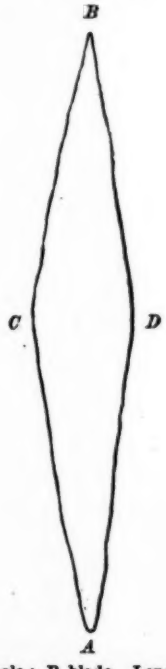


FIG. 1.—*A*, pole; *B*, blade. Length from *A* to *B*, 10¾ inches; thickness from *C* to *D*, 2⅝ inches.

Will's Creek, varies in thickness from two to ten, and in some places twenty feet, and the point at which this implement of the Paleolithic age was found is about five or six feet beneath the original surface—the soil, gravel, sand, and water-worn bowlders having been carried over the declivity into Will's Creek by rains or other means.

This remarkably large relic of by-gone ages has a very sharp edge, compared with hundreds of the small Indian axes and hatchets, so called, found in many parts of this country. It weighs seven and a half pounds, measures eight and a half

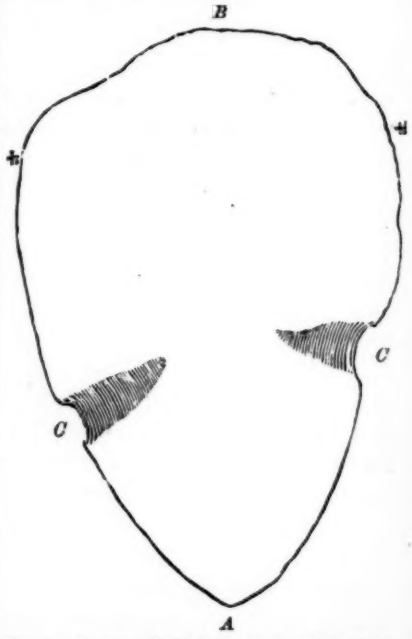


FIG. 2.—*A*, pole; *B*, blade, edge very sharp from mark to mark +, then thickens abruptly; *C C*, thong-marks.

The lithological character of this relic of the Stone age is that of a dark-blue cherty, siliceous and coralline limestone of the Paleozoic age, and, possibly, of an upper silurian stratum, as it very much resembles some of those fossiliferous strata, and, in fact, presents on one side what very much resembles a large (but not very distinct) polyparium of the fossil coral lichenalia concentrica of Prof. Hall's "Paleontology of New York," vol. ii., Plate 37, A.

inches around the sharp edge of the blade; it is ten and a half inches long, seven and three-quarters inches across the widest part of the blade; is two and five-eighths inches through from side to side, and tapers gradually toward the pole to a sharp point, in a

similar manner to the stone axes of the ancient Celtic tribes, so frequently found in some portions of England, Ireland, and Scotland.

On the plateau above named, bowlders of many hundred weight are thickly scattered, which could have been deposited in their present locality by floating ice only, and it is more than likely that this relic of the Primeval or Stone age was brought to this locality and deposited by the same agencies that brought the bowlders and other detritus, perhaps, from a very distant region.

The thong-marks for securing the handle are well preserved, but were deeper when first taken from the ground, as there was a full sixteenth of an inch of semi-decomposed material rubbed off in cleaning it up. The stone from which it has been made appears to have been a portion of one of those hard, cherty strata of coralline limestone, belonging to the silurian formation, some of which are harder than flint, and almost as tough as iron. The implement, as it is now, is dark blue on one side, but lighter on the other. This lighter side appears to have yielded more readily to the action of the elements, decomposition having apparently removed at least a quarter of an inch more on this side than on the other, thus materially reducing the weight of the specimen. This battle-axe was found on January 4, 1876.

WILLIAM ANDREWS.

CUMBERLAND, MARYLAND.

To the Editor of the Popular Science Monthly:

SIR: In your notice of Mr. John Fiske's criticism of Dr. Draper's "Conflict" you have shown, plainly enough, that Dr. Draper's alleged superficiality consisted in using the word religion in the common sense.

That Dr. Draper's conceptions are so "crude" as to blind him to the higher and more spiritual conceptions which Mr. Fiske defines so admirably, or that he would consider religion, so defined, in antagonism with science, is an assertion which finds no warrant in his book. It would be easy, if it were worth while, to point to passages that explicitly negative such imputations. But to have adopted Mr. Fiske's rather transcendental refinement, and to have constantly used the qualified terms which it would require, would have been to sacrifice directness and brevity to a nicety of expression that none but the hypercritical would demand.

Your quotation shows that Mr. Spencer's "First Principles" must fall within the list of books which, "vitiated by this crude conception" (of antagonism), "cannot have much philosophical value;" and I beg to append another from a work which, it would seem, must come into the same class, although it is by an author evidently held in high esteem by Mr. Fiske:

"*That harmony which we hope eventually to see established between our knowledge and our aspirations* is not to be realized by the timidity which shrinks from logically following out either of the two apparently conflicting lines of thought—as in the question of matter and spirit—but by the fearlessness which pushes each to its inevitable conclusion. *Only when this is recognized will the long and mistaken warfare between Science and Religion be exchanged for an enduring alliance.*"—(FISKE'S "Cosmic Philosophy," vol. ii., p. 509.)

E. R. LELAND.

EAUCLAIRE, WISCONSIN, *July* 20, 1876.

GEOMETRICAL CHEMISTRY.

To the Editor of the Popular Science Monthly:

GEOMETRICAL CHEMISTRY. By HENRY WURTZ. First, or Introductory Memoir. Reprinted from the *American Chemist*, for March, 1876. New York: John F. Trow & Son. 1876.

THE author prefixes a Greek motto to his memoir, namely, the question, "Wherefore did Plato assert that *the* GOD worketh ever by geometry?" As the memoir contains no other geometry, this motto apparently is intended to justify the first half of the title.

But the other half has not even that much of a justification. From beginning to end it is impossible to detect a new principle or fact that properly belongs to chemistry in this memoir. The great chemical authorities of the memoir are Kant, Hegel, Stallo, and Sterry Hunt (p. 60). A new force, the *Cratetic Force*, is discovered, "which is *not* reciprocal, but absolute in its action upon the more electro-positive molecule, *without* reac-

tion upon the electro-negative one" (p. 69). Hence the equality of action and reaction must now be thrown to the resting-place of *horror vacui* and kindred errors.

Having reached the end of the memoir without encountering a single scientific result, I felt greatly relieved by the author's modest statement (p. 72): "I claim to have discovered and demonstrated the same grand geometrical laws which Kepler traced as ruling the planetary system, as prevailing also in the microcosms which we call molecules." And the author complacently continues: "I must add that, though many advanced chemists have long expected some great revelation from this source, yet *now that a revelation has come*, there are few even among the boldest and most original thinkers who will not be *startled* at the sweeping, in some respects revolutionary, tendency of these developments, with regard to the current theories of the schools and the school-books."

I confess to have indeed been thoroughly "startled" to see such a paper as this printed *in extenso* in the *American Chemist;* and not much less astonished to find it recently (May 27, 1876) partly reprinted in the *Engineering and Mining Journal*, accompanied by a highly-laudatory editorial, wherein Dr. T. Sterry Hunt is reported to have expressed the opinion that "Prof. Wurtz has surprised Nature in one of her secrets, and has enunciated a law which is probably as important as the law of the force of gravity."

It is simply because these high and unqualified indorsements are likely to give the vagaries of "Geometrical Chemistry" currency in the popular scientific press of the country that I take the trouble to expose the palpable fallacy of the whole fabric.

The inorganic chemical compounds contain oxygen as the most general constituent, while the organic compounds contain as generally carbon. Hence, if we were to mystify some of our chemical colleagues, not very sound in elementary mathematics, we would calculate the densities of all compounds by assuming almost any fixed atomic volume for these two elements, and assigning the residual volume to the other constituents. By a liberal use of arbitrary multiples, these residual volumes could then be very readily expressed as cubes (or almost any other function) of whole numbers with so great an approximation that inversely the calculated density of the compound must be almost identical with *any*[1] of the observed values of the same. Such a process, when presented by a sufficiently funny man in Section Q of the American Association, would be very entertaining; but when such a thing occupies twenty quarto pages in the *American Chemist*, and when voluminous extracts thereof in other scientific journals are printed as embodying great chemical progress, I feel that American science has been disgraced.

Prof. Wurtz in the above mystification proves himself not even sufficiently master of arithmetical puns to keep the variations of the positive elements (the above residual) within bounds. A slightly more dexterous use of the convenient arbitrary multiples would have helped him out, and yielded numerous new "laws." Thus the hydrogen diameter ranges from 16 to 28, that is, in volume it ranges as the cubes of these numbers, from 4,096 to 21,952, in proportion of one to five in closely-allied compounds! In very closely-related compounds of aluminium the diameter of aluminium varies from 16 to 45, its volume therefore from 4,096 to 91,125, or in the proportion of one to twenty-two! (*See* pp. 54–57.)

Space forbids my entering upon a more detailed *exposé* of this crude display of indeterminate analysis. The whole thing is so utterly worthless, so absolutely destitute of every gleam of science, so horridly uncouth even in its verbal exposition, that this short notice is most reluctantly given, simply to protest, in the name of American science, against the filling of our *scientific* journals with material that exposes us to the ridicule of the scientific world.

GUSTAVUS HINRICHS.

IOWA CITY, IOWA, *July* 21, 1876.

[1] The influence of impurities, etc., is coolly ascribed to arbitrary variations in atom-diameter and varying multiples in the molecule; this is done even for minerals and metals! I wonder that Mr. Raymond did not see the absurdity of the whole process. See, for example, "Siderite," p. 82, or in fact any substance for which more than one density has been used.

EDITOR'S TABLE.

FRENCH EXPERIENCES WITH PAPER-MONEY.

IN his pamphlet entitled "Paper-Money Inflation in France: How it came, What it brought, and How it ended," President White tells a very plain and direct, but a very exciting story of national folly and infatuation. It sounds like romance, and but for the constant citations we should almost suspect that the writer is treating us to a satire on American finance. Yet he only gives us a cool, matter-of-fact delineation of a great national experiment in the substitution of irredeemable paper for coin as a circulating medium. The lesson brought out by this impressive narration is, that there are natural laws which govern the business operations of society just as inexorable as the physical laws that maintain the harmonies of the solar system or the physiological laws that control the life-processes of the human body. But in the realm of social operations this truth is not recognized. In consequence of public ignorance upon this point, and the stupid superstitions of the people regarding the potency of legislation, this great field of human effort is the intrenchment of imposture in a hundred shapes, where designing quacks and credulous dupes, calculating demagogues, purblind reformers, and humbugs of every stripe, have free course and unrestrained revel. This is a sphere in which it is believed that Nature can be cheated, and the consequences of human actions escaped. The laws that connect human well-being with self-restraint, that require present sacrifice for future good, and make comfort and competence dependent upon industry and frugality, are held to be the mere hard conditions of human lot, which, being evaded by many, may be avoided by all through cunning political schemes and proper legislative ingenuity. There are still millions in this country who have a kind of vague faith that irredeemable paper-money such as a government can print and scatter without limit is a means of national prosperity, a fountain of public wealth, an equalizer of fortunes, a blessing to the poorer classes, and a grand defense of society against the evils of poverty and privation. That it is an illusion and a snare, full of danger, and offering transient benefits at the expense of final disaster, it is difficult to make them understand.

Let people in this state of mind acquaint themselves with the experience of the French upon the subject by reading President White's statement. We give its leading points, quoting his own words freely: The year 1789 was one of stagnation and financial embarrassment in France. The nation had a heavy debt and a serious deficit, and there was scarcity of money and a want of confidence. This was a time of trial and a test of statesmanship. There were those who saw that the evil could only be remedied by patience, careful management, and the strict adherence to established financial principles. But others, as Dr. White says, were "looking about for some short road to prosperity, and ere long the idea was set afloat that the great want of the country was more of the circulating medium; and this was speedily followed by calls for an issue of paper-money." There was then a struggle. The dangers of such a course were vividly depicted on the one hand, and on the other it was maintained that it would be the salvation of France. On the 19th of April, 1790. the finance committee of the

French Assembly reported that "the people demand a new circulating medium;" that "the circulation of paper is the best of operations;" that "it is the most free, because it reposes on the will of the people;" that "it will bind the interests of the citizen to the public good."

The Government had appropriated the vast property of the French Church, amounting in value to about four thousand million francs, and this was to be the security of the paper. Accordingly, in April, 1790, the "Government issued four hundred million francs in assignats — paper-money secured by a pledge of productive real estate, and bearing interest to the holder at three per cent." What could be more secure? It was maintained that such a currency would immediately prove itself better than coin.

"The first result of this issue was apparently all that the most sanguine could desire; the Treasury was at once greatly relieved; a portion of the public debt was paid; creditors were encouraged; credit revived; ordinary expenses were met, and the paper-money having thus been passed from the Government into the midst of the people, trade was revived, and all difficulties seemed past."

Possibly, if the Government could have stopped with these temporary advantages, no great harm would have been done. But the difficulty about money is, that there is never thought to be enough of it. The benefit of real money (coin) is to set a stubborn limit to this universal want—it cannot be got without earning it or giving equivalent property for it. The curse of pseudo-money (irredeemable paper) is, that it panders to the universal greed because any amount of it can be manufactured and set afloat at any time. And so, of course, the French, after the first taste, wanted more. The further issue was stoutly resisted by the ablest men, but the current set so strong, and the demagogues were so plausible, that the measure was carried, and in September the Government issued eight hundred million assignats, "solemnly declaring that in no case should the entire amount put in circulation exceed twelve hundred millions."

Great were the rejoicings on every side. Gold was to lose all value, as it was a superfluity, and the nation was committed to the policy of inflation. But the old cry of the "lack of a circulating medium" soon broke forth again. A hundred millions were issued under the plea of a want of small notes. On June 19, 1791, less than nine months after the former great issue, six hundred millions more were put in circulation. Next came depreciation of the currency, a loss of its purchasing power, and a rise in prices. Some said that this was due to ignorance in the rural districts, and the remedy proposed was "education of the people." M. Prudhomme's newspaper, however, declared that "coin will keep rising until the people have hung a broker." People naturally began to be alarmed, and to convert the paper into coin and hoard it up. This was regarded as criminal, and Marat asserted that death was the proper penalty for persons who thus hid their money.

But, after the first stimulus of these issues, business soon became depressed, trade stagnated, the manufactories were closed, and thousands of workmen were discharged. Uncertainty and fluctuation of values followed, speculation set in, and, in the language of Louis Blanc, "commerce was dead; betting took its place." "In the cities now arose a luxury and license which is a greater evil than the plundering which ministers to it. In the country the gambling spirit spread more and more; nor was this reckless and corrupt spirit confined to business-men; it began to break out in official circles; and public men who, a few years before, had been

pure in motive, and above all probability of taint, became luxurious, reckless, cynical, and finally corrupt. . . .

"Even worse than this was the breaking down of morals in the country at large, resulting from the sudden building up of ostentatious wealth in a few large cities, and the gambling, speculative spirit fostered in the small towns and rural districts."

There was no stopping now. The artificial quickening had gradually run into a feverish activity, followed by intoxication, which had grown into a regular national debauch. Every issue of paper-money had made matters worse. But so deep was the infatuation that multitudes of people insisted that if there were only *enough* paper-money all would be well. On December 17, 1791, a new issue was ordered of three hundred millions more, and on April 30, 1792, still another three hundred millions were thrown out. The currency was now depreciated thirty per cent., and in July of the same year another three hundred millions were emitted. "Issue after issue followed at intervals of a few months until, on December 14, 1792, we have an official statement that thirty-four hundred millions had been put forth, of which six hundred millions had been burned, leaving in circulation twenty-eight hundred millions."

As articles of common consumption grew enormously dear, their holders became unwilling to sell them for the worthless currency with which France was flooded, and there then arose a demand that those who refused to make such exchanges should be punished with death. Laws were passed making the sales of goods compulsory at fixed prices in paper-money, which were, of course, inoperative. In 1793 there was an enactment forbidding the sale or exchange of specie for more than its nominal value in paper, under a penalty of six years' imprisonment in irons; and then twelve hundred millions more of the inflated currency was thrown out. "Toward the end of 1794 seven thousand million assignats were in circulation. By the end of May, 1795, the circulation was increased to ten thousand millions; at the end of June, to fourteen thousand millions; at the end of July, to sixteen thousand millions; and the value of one hundred francs in paper fell steadily first to four francs in gold, then to three, then to two and a half." The issues continued until, at the beginning of 1796, they amounted to over forty-five thousand million francs. One franc in gold was worth two hundred and eighty-eight francs in paper-money; sugar was five hundred francs a pound, and carriage-hire six thousand francs a day in the legal currency. Debts were, of course, now easily paid.

The madness continued, but its form was diversified. In 1796 "it was decreed that no more assignats be issued; instead of them it was decreed that a new paper-money, 'fully secured and as good as gold,' be issued, under the name of 'mandats.'" Choice public real estate was set apart to secure this money, but it speedily depreciated ninety-five per cent. It was decreed that those who refused to take it should be fined and sent to prison, and that those who even spoke against it should incur the same penalties. But the end at last came. On July 16, 1796, "it was decreed that all paper, mandats and assignats, should be taken at its real value, and that bargains might be made in whatever currency the people chose. The reign of paper-money in France was over. The twenty-five hundred million mandats went into the common heap of refuse with the previous thirty-six billion assignats. The whole vast issue was repudiated. The collapse had come at last; the whole nation was plunged into financial distress and debauchery from one end to the other."

We have given the bare skeleton

of facts contained in President White's pamphlet, but with nothing of his admirable analysis and exposition of the working of this great financial experiment. Let none fail to read and ponder the document. It is a lesson in one branch of political economy that our citizens cannot afford to neglect, and we are glad to be able to state that the publishers have issued an edition for universal circulation, as a campaign document needed at this time by both parties, and at a price so low that it may be distributed everywhere.

THE STATUE TO LIEBIG.

It is proposed to raise a statue in Munich in honor of the illustrious chemist Liebig. No man better deserves such a tribute, for the claims of Liebig upon the appreciation and gratitude of the civilized world are unique and unrivaled. Starting from obscurity, he made his way by the pure force of genius alone, selecting his line of study even in boyhood, when he was snubbed by his teachers for the stupidity of his choice; he gave himself to chemistry early, unreservedly, with the enthusiasm of a vehement nature, and pursued it with indefatigable industry almost to the day of his death. He became a leader in this field in early life, became the acknowledged master amid a host of powerful competitors, and died the greatest chemist in Germany. The influence exerted by Liebig in the advancement of his favorite science it is hardly possible to over-estimate. His original investigations, each of which pushed forward the branch of inquiry to which it was devoted, are numbered by hundreds, so that, as Dr. Hoffman, in his recent eulogy, justly observes, "Were we to consider merely the vast number and incalculable importance of the chemical facts which he has established, we should have to proclaim him one of the greatest contributors to chemistry at large that ever have appeared, while of organic chemistry we could not hesitate to consider him the very source and fountain-head."

Liebig was a great experimenter, but that is not his highest title to eminence as a chemist. He enriched the science by new methods of analytic research, and invented the apparatus which gave a new impulse to organic investigations and made an epoch in organic chemistry, and he vastly enriched the science by varied and extensive laboratory researches. But it was not merely by these inquiries that he made the deepest impression upon the mind of the age. He was not only an experimenter, but a thinker; not only a chemist, but a philosopher; and it was in his grasp of principles and the establishment of general laws that we recognize his highest genius. Chemical analysis, the revision and correction of old processes, and the elucidation of new facts, are of course important and meritorious things, and in this field men of moderate ability may make valuable and permanent contributions to the progress of science. But it requires the insight of a higher genius to pierce through the multitudinous mass of isolated results, and bring out the principles that reduce them to order and bring them into living correlation with the general organism of scientific truth. This was the distinguishing character of Liebig's work in the chemical field. When he began his labors, physiological chemistry had hardly a foothold of recognition. The vital force was supreme in the realm of life, and was held to suspend and override all chemical and physical agencies. Liebig made a revolution by showing that a true physiological science can only be established by interpreting vital processes in the light of chemical and physical principles.

But the scientific fame of Liebig has a yet broader basis. He is the father of agricultural chemistry. Not only did he contribute largely to the eluci-

dation of fundamental problems in this branch of study, and first give to it its recognition and status in the scientific world, but by the skill of his pen, his power of exposition and untiring industry, he aroused a popular interest in the subject which was felt through all the nations of civilization. Though a chemist, his name became as familiar in the households of this country as those of Newton and Shakespeare, while his work was recognized as having a practical beneficence that involved alike the prosperity of individuals, communities, and states. For, to give an impulse to agriculture, and to arouse the thought and quicken the intelligence of the agricultural classes, was to contribute essentially to the advancement of civilization itself. Whoever thinks that this is an exaggerated estimate of the claims and character of Prof. Liebig, may read with profit the admirable discourse of Dr. A. W. Hoffman, of the University of Berlin, on "The Life-Work of Liebig," delivered last year in London, and just published by Macmillan. It is not only a worthy tribute of a grateful pupil to his illustrious teacher, but it is a most admirable and discriminating estimate of the man in his relations to the progressive science of the age. We say, then, let all who believe in honoring the achievements of great men by erecting statues to their memories contribute toward the erection of this statue to Liebig. We ought to have one erected in the Central Park; but, if that be impracticable, let it be done in Munich. At the recent dinner given by the American Chemical Society to the foreign chemists connected with the Centennial Exhibition in Philadelphia, it was announced that Dr. Hoffman asks from this country a contribution of $2,500 to complete the work. Chemists, as a class, do not abound in this world's goods, but $1,000 was pledged for the purpose on the spot. Our enterprising and successful agricultural friends should have a hand in this work; and, if any are disposed to help it on, their contributions may be forwarded to Prof. E. N. Horsford, of Cambridge, or to Prof. C. F. Chandler, of New York, who will forward any funds that may be intrusted to them to the foreign committee who have the work in charge.

HAMILTON ON "SOCIAL SCIENCE."

Mr. R. S. Hamilton, considering himself very badly treated in our notice of his book, made some time ago, pays us off in an article which appears in our pages this month. He lays it on to the editorial back without mercy, and nothing remains for us but to kiss the rod and resume the subject. Perhaps we are obtuse, but, having again looked over his volume, and our remarks upon it, in the light of what he now says, we are still unable to see that we have done him the injustice of which he complains.

Mr. Hamilton admits that our main accusation—and almost the only one—was, that his book is "old." Let us see, then, what ground he has for protesting against this position. Had he designated his volume by its secondary title, "A Review, Historical and Critical, of the Progress of Thought in Social Philosophy," which would have better described it, our criticism would have been uncalled for; but by putting it forth under the name of "The Present Status of Social Science" he invited attention to it as a report, up to date, on a highly-important and rapidly-developing subject. The Popular Science Monthly had but little interest in the historical and critical features of his work; but it was interested in its claim to inform its readers of the present attitude of a great science. Taking it up from this point of view—the view challenged by the author in the adoption of his title—we said it was "old." Not that we have the slightest objection to old books if they are good, or

to old ideas if they are true, but only that it becomes sometimes necessary in science to discriminate between past and present conditions, although the past be quite modern. We did not, of course, consider the book old in the sense of the Assyrian inscriptions, but rather in the sense of a last year's almanac, which, although recent, still fails to indicate the present status of astronomical movements.

We said in our notice that the author "seemed to have but an obscure conception of social science," the implication of course being that his book is behind the age. He replies that "social science is a very large science," and may present different aspects to its different cultivators. But surely this need not imply obscurity in the conception of the science itself. Astronomy, geology, and biology, are very large sciences, and, no doubt, present different aspects to investigators in the same field, but this by no means necessitates vagueness or obscurity in the ideas of the aim, subject-matter, or methods, of either. There is common and well-determined work to be done in each, regardless of its extent.

But we were not left to inference in imputing to the author obscure conceptions upon the subject, for, according to him, no others are at present possible. In the first chapter of his book he says that "this important science has not yet attained to just, clear, and definite ideas as to its true and proper ends, and consequently it has not yet learned how even to begin its inquiries properly, how to direct its efforts, or systematize its observations. For this is precisely the present condition of social science." The obvious conclusion from this is, that as yet there is no such science. Its "status" is therefore in substance nothing, and in place nowhere, while the attempt to state it must needs be superfluous and impossible. This is a view that might have been held any time these thousands of years, and we think may be properly characterized as "old."

Mr. Hamilton labors to show that he was right in holding Herbert Spencer responsible for his "Social Statics," and denies that the modifications of opinion, which the author of that work declares he has undergone since its publication twenty-five years ago, are to be regarded as "important." Well, that depends upon the estimate he puts upon accuracy of representation. Mr. Hamilton's view of what is "important" in such cases will certainly not pass muster among scientific men, who are generally and properly emphatic in the assertion of their rights in this particular. They insist upon being judged only by the latest expression of their views, and chemists, physicists, and physiologists alike refuse to be bound by the old editions of their works. Mr. Spencer's modifications of opinion were held so important by himself that he strenuously resisted the republication of the book in this country when out of print in England; and, when overruled in this, he interposed a preface, warning his readers that it was no longer a truthful expression of his views. While not absolutely repudiating it, and while still adhering to its general conceptions, he yet declares that the theory which it enunciates has been so variously modified and further developed that he does not abide by its detailed applications. Several positions in the work are explicitly disavowed, and it is obvious that his changes of view affect its whole complexion. Mr. Hamilton attacked his chapter on "The Evanescence of Evil" with results satisfactory to himself; yet he could hardly fail to see that the argument of that chapter is merged in the great principle of Evolution, which has received its almost entire scientific development since the date of "Social Statics," while Mr. Spencer has been a leading student of that subject, and made it the foundation of his philosophy.

But Mr. Hamilton had before him Spencer's direct assertion that the doctrine underlying that part of the book (which contained the discussion on "The Evanescence of Evil") as there stated is but an adumbration of the view which he now holds. Is there no "important" difference between the dim foreshadowing of a principle and its distinct presentation with the limits and qualifications that result from years of research and reflection? Mr. Spencer declared, besides, that he could not revise "Social Statics" without great labor; and what does this imply but that the changes of the work would have to be extensive and important? Moreover, he has been long engaged upon the systematic extension of the subject to which his first book was dedicated, and he expresses the hope to set forth in due time "the developed conclusions of which 'Social Statics' must be regarded as a rough sketch."

A painter would not like to be critically judged by a rough sketch, and would consider it very important that judgment should be suspended until the work was finished—why not, then, a literary or a scientific artist? It was well enough, of course, for Mr. Hamilton to attack Spencer's old book, and riddle and ridicule it to his heart's content, if he thought it worth while. But, as his thesis was "the present status" of the great subject to which Spencer is devoting his life, he was bound in all fairness to let his readers know both how Mr. Spencer regarded his early treatise, and the import of his subsequent labors upon the same subject. Thirteen years before Mr. Hamilton's book was published Mr. Spencer had printed a programme giving a detailed outline of the course of thought by which alone, in his opinion, Sociology can be logically reached and scientifically unfolded. Mr. Spencer's position as a thinker was such as to command the high respect of eminent men, who indorsed his undertaking at the outset as one of great public importance. But of this Mr. Hamilton gives us no intelligible account, although Spencer's prospectus alone was a sufficient refutation of the statement that clear and definite ideas have not yet been reached regarding the true ends and methods of social science. The prominence that Mr. Hamilton gives in his own book to "Social Statics"—a work that Spencer, in elucidating the principles of social science, has left far behind—sufficiently shows that his treatment of the *science* of society is not up to date.

But, aside from the point of view we took in our very brief notice of Mr. Hamilton's book, we have no hesitation in saying it is a volume of much interest. It contains a good deal of valuable information and instructive discussion, "historical and critical, in relation to the progress of thought in social philosophy." It is only with regard to the social science which he professes to have triangulated, and fixed its latest position, that we think he is somewhat befogged—just sufficiently, perhaps, to entitle him to the perpetual presidency of the American Social Science Association.

PROF. HUXLEY.

THIS gentleman is evidently very much wanted in the United States. There is great anxiety to see him and hear him speak. The applications to secure lectures from him are numerous and urgent, the applicants being determined not to take no for an answer. It is a repetition of the experience with Tyndall four years ago, and the fact is significant, as showing that public interest in science is not a transient thing. In the case of Prof. Tyndall it was alleged by many that his brilliant experiments were the attraction, and that people went to his lectures impelled by the same motive that draws them to a pyrotechnic show. Of course, this was not true, but no such reason can be

assigned for the desire to hear Prof. Huxley, as he never experiments. His chosen department of science is one of the most difficult, and the questions he discusses are profound. Undoubtedly in the great movement of thought in this age Prof. Huxley's topics are prominent, and many agencies have conspired to give them wide public interest; but we have to reckon Huxley's genius as one among the potent forces that in recent years have determined this course of public thought. Thus far we on this side know him only as a writer, and his remarkable powers in this respect are so well understood that nothing need be said about them here. But his accomplishments as a lecturer are quite equal to those displayed in his books. Said a distinguished English scientist the other day, who had come over as a Centennial juror: "And so Huxley is to be with you, and is going to lecture. Well, those who hear him will have a treat, for as a scientific lecturer he is unequaled. Next to John Bright I regard Huxley as the best orator in England; at any rate, in exposition, in elucidating a complex subject before a popular audience, we have no man to compare with him." Prof. Huxley's manner as a speaker is very quiet, and by those who like the vehement and demonstrative style it would be considered tame, but his discourse is clear, finished, deliberate, and strong. Nor, is it necessary that he should have a learned auditory to appreciate and enjoy his addresses. His command of his subject, of language and illustration, is so complete that he adapts himself with rare facility to the mental condition of his hearers. One of the most successful efforts we ever witnessed upon the platform was a lecture on physical geography given by Huxley to the working-men of London who filled to its last corner the large lecture-room of the Jermyn Street School of Mines. We had heard him before on ethnology at one of the "Friday evenings" of the Royal Institution before the *élite* of scientific London. It was an admirable discourse, and was listened to with the keenest attention and a lively pleasure, though how much of its success might be due to the cultivated character of the assemblage it was not then easy to say. But his Jermyn Street audience consisted of unlettered, hard-handed working-men, and yet there was not one among them that did not follow the speaker understandingly and with evidently as great enjoyment as the most cultured listeners. Prof. Huxley will be sure to please his American audiences, and, considering how much good he might do us, it is unfortunate that he cannot stay longer and speak in our chief cities. In the short course of lectures which he has consented to deliver in New York he will take up a subject which has long occupied him, upon which he is an authority, and which is certain to be treated in a manner that will gratify all who have the good fortune to listen to him. We announced last month that the lectures will take place on the 18th, 20th, and 22d of September, and that those desiring to secure seats could do so by registering their applications with D. Appleton & Co. The seats have been rapidly taken, and, as there is only a certain number of them, we must again remind those whom it may concern that when they are all bespoken no more can be had for love or money.

LITERARY NOTICES.

THE AMERICAN CYCLOPÆDIA: A Popular Dictionary of General Knowledge. Edited by GEORGE RIPLEY and CHARLES A. DANA. 16 vols., 13,314 pages. Price (cloth), $80.

THIS Cyclopædia, the first edition of which was completed in 1863, having proved its adaptation to the general wants by a very extensive sale, has now undergone complete revision, and, while preserving its

well-known character, comes forth essentially a new work. Considerable portions of the original remain intact, where nothing has occurred to impair the accuracy of the statements; yet such are the activity of research and the vigilance of criticism in all departments of knowledge that but few subjects remain unaffected, and a large number of articles have required to be added or amplified, corrected or retrenched, so as to make the work thoroughly trustworthy, and to bring its multitudinous contents into proper symmetry and proportions. The changes in the new edition are marked. It has been freely illustrated throughout wherever engravings could help the text, and the scientific and political articles have been all rewritten, while the utmost pains have been taken to bring the endless details up to the latest standard of accuracy. Of course, the work is not free from imperfections, because knowledge itself is imperfect; but whatever could be done by the ability and experience of the editors, by their extensive corps of able contributors, and by the liberal expenditure of the publishers, to make the Cyclopædia worthy of public confidence, has certainly been accomplished. We say this without hesitation, and know something of that which we affirm. The office of the staff of editors of the "American Cyclopædia" adjoins our own, and for the past four years we have watched their proceedings with a lively interest and no little admiration. Having the advantage of a thorough apprenticeship in the preparation of the first edition, the editors were enabled to organize the work of revision in the completest manner from the start, and it has been carried on with unrelaxed assiduity, with a disciplined cooperation—an effectiveness of method and a conscientious caution that have brought the whole talent of the force into a focus, as it were, upon each page in its preparation for the press.

But in judging the merit of a cyclopædia we have to look further than this. Such a work may be a monument of careful labor, which is still misdirected. The question remains, What is its purpose, and how is its design fulfilled? There are cyclopædias upon all subjects, commerce, chemistry, agriculture, technology, fine art, engineering, and various other branches of knowledge; and they have special values, of course, for the cultivators of those branches, though very little value for general use. It is folly to expatiate upon the accuracy and fullness of a cyclopædia of antiquities, for example, to one who cares nothing about the subject. To a politician a cyclopædia of the physical sciences, however faithfully executed, would be but rubbish with which he would hardly cumber the shelves of his library. A cyclopædia is therefore to be judged primarily by its adaptation to the class for which it was prepared. The "American Cyclopædia," as a comprehensive and popular dictionary of general knowledge, appeals, not especially to this class or to that, but to intelligent people everywhere who desire a work of reference on all topics of current and general interest. More than any other work that has yet appeared, the "American Cyclopædia" is adapted to the daily uses and wants of American families. Its matter is chosen, harmonized, proportioned, illustrated, and put into literary form, we might almost say, with reference to their needs; and certainly, as a means of education in the family, its value is hardly to be over-estimated. It is a library of itself, in which the best information upon many thousands of subjects has been condensed so as to be quickly found at any moment when it is wanted. As books multiply until they become burdensome, and the pressure upon the time forbids their being read, we are more and more driven to the summaries of human knowledge, in which the husks of interminable talk are stripped away, and we are furnished with essential facts and compendious results. Hence the recent and growing popularity of encyclopedic literature. No agency of intellectual cultivation can be introduced into the family so direct and efficient in its quickening, enlarging influence upon the minds of the younger members of the family circle as a comprehensive, carefully-digested cyclopædia, convenient in form, for ready, habitual reference. It answers questions, solves difficulties, corrects errors, imparts varied and valuable information, and kindles the desire for mental cultivation. We say it does this; it does it in many instances, and would do it in many more if its importance were better understood. It must not be

forgotten that a cyclopædia in a family, like a piano, must be used to be good for anything. It should be ready of access; and, instead of keeping it away in the library, or locking it up in a stately bookcase, it should be placed in a separate and open case in the room most commonly occupied by the family, and where the volumes can be reached by the very smallest amount of effort. By adopting this plan, a bright family will soon find the Cyclopædia among the first of daily necessities, and a source of constant pleasure and instruction. The publishers have anticipated this want of separate cases for their work, and supply them when desired; but any cabinet-maker will manufacture them at a trifling cost.

DARWINIANA: Essays and Reviews pertaining to Darwinism. By ASA GRAY. New York: D. Appleton & Co. Pp. 390. Price, $2.

THE appearance of this volume will take many people by surprise. Although Prof. Gray is widely known in the world of science for his botanical researches, and in the world of education by his valuable text-books, but few are aware that he is a pronounced and unflinching Darwinian, or that he has been an able and vigorous defender of the doctrines that pass under this name, ever since they were first promulgated. He has written much upon this subject in various periodicals, but, caring only to let the arguments go for what they are worth, he has modestly withheld his name from the articles, the effect being that his position upon the question has not been a matter of notoriety. His contributions to the discussion are varied and valuable, and, as collected in the present volume, they will be seen to establish a new and unexpected claim upon the thinking world, which we are sure will be extensively felt and cordially acknowledged.

The history of what may be called the Darwinian discussion, in some of its aspects, is most curious and instructive. We complacently point back to those narrow and prejudiced times, from which we have happily escaped, when novel scientific opinions were rejected on the most frivolous and puerile grounds, urged by those who knew nothing whatever about them. But have we really much improved on those old practices, and do we even yet recognize that plain rule of common-sense, to leave the discussion of serious and difficult scientific questions to those who are competent to deal with them? Our times are eminent for just the contrary procedure. With all our vaunted liberalization, we dare not leave scientific questions to scientific men. In the history of the scientific controversies of the last three centuries there is no instance that will compare with this of "Darwinism," when the community has been so bewildered and misled by irrelevant and childish discussion on the part of grossly incompetent writers. The press has teemed with essays and books by men who were not only unfamiliar with the problems involved, and utterly ignorant of the sciences upon which their solution depends, but who had no intelligent conception even of the issues to be settled. Clergymen, lawyers, metaphysicians, *littérateurs*, having no acquaintance with natural history, and knowing nothing of the requirements, difficulties, and perplexities of scientific investigation, have rushed into the debate with a confidence and pretension contrasting strongly with the spirit of those who have given their lives to the study. Here comes another of these impudent and worthless performances, "A Critical Examination of some of the Principal Arguments for and against Darwinism," by James Maclaren, M. A., barrister-at-law; and what are the claims of this writer to attention? Why, he has written a book on the "History of the Currency;" and, with the mental equipment which such a work and his professional education imply, he assumes to deal with the greatest problem that has ever presented itself to the mind of man, a problem which belongs purely to science, and is engrossing the severest scrutiny of the most thoroughly disciplined scientific minds of the age.

Dr. Gray's book offers a refreshing contrast to this shallow strain of Darwinian literature. It comes of a direct, first-hand, and thoroughly familiar knowledge of the elements and objects which enter into the inquiry, and outweighs whole libraries of such productions as we have here referred to. The author says, in his preface: "If these papers are useful at all, it will be as showing how these new views of our day are regarded by a practical naturalist, versed in

one department only (viz., botany), most interested in their bearings upon its special problems, one accustomed to direct and close dealing with the facts in hand, and disposed to rise from them only to the consideration of those general questions upon which they throw, or from which they receive, illustration." It is this characteristic which gives its eminent value to Dr. Gray's volume. On such a grave question, what we want to know is the intelligent opinion of men capable of forming an independent judgment, and a statement of the evidence on which they base their conclusions. The promulgation of Darwin's theory, in 1859, found Prof. Gray a trained student of the biological problems presented by the vegetable kingdom. With an extensive and accurate knowledge of plants, and a philosophical turn of thought which could not evade the question how the vast diversities of the plant world have been brought about, he had a solid preparation for judging of the claims of the "Origin of Species." Convinced of the total insufficiency of all previous theories upon the subject, he saw at once that Mr. Darwin's view was a great step forward in the pathway of science, resolving difficulties before insuperable, and promising to be of immense service in organizing existing knowledge, and in opening avenues of future investigation. The next year after the issue of the "Origin of Species," he published an elaborate article in the *American Journal of Science*, reviewing and interpreting it, and contrasting its doctrines with those advocated by Prof. Agassiz. This is the opening paper of the present volume, and was followed by a series of essays which appeared in various magazines, taking up many aspects of the subject, answering objections, elucidating obscurities, criticising adverse works, and contributing important additions to the general theory. These papers, as now printed together, not only illustrate the history of the controversy, and the progress of the discussion, but they form, perhaps, the fullest and most trustworthy exposition and illustration of what is to be properly understood by "Darwinism" that is to be found in our language. Of course, the work is not a systematic treatise upon the subject, but it covers the chief points that are of paramount interest, both to naturalists and to general readers.

But there is another feature of Dr. Gray's volume which will commend it, in even a higher degree, to large portions of the public. It gives earnest and prominent attention to the religious aspects of the question. Though a thorough-going Darwinian, Dr. Gray will not consent to hold his scientific opinions at the expense of his religious faith. Satisfied that the great principle of "Natural Selection" is a powerful working law of Nature, and holding to cardinal theological beliefs, he maintains that the conflict between them is not necessary, and that an enlightened interpretation of religious doctrine must bring it into harmony with the advanced scientific conclusions. Nor is it a mere semblance of faith that is to be harmonized with science by frittering away its essential character. Dr. Gray is out and out orthodox, and eminently sound in his theology. In his preface he says:

> "Then as to the natural theological questions which (owing to circumstances needless now to be recalled or explained) are here throughout brought into what most naturalists, and some other readers, may deem undue prominence, there are many who may be interested to know how these increasingly prevalent views and their tendencies are regarded by one who is scientifically, and in his own fashion, a Darwinian, philosophically a convinced theist, and religiously an acceptor of the 'creed commonly called the Nicene,' as the exponent of the Christian faith."

This portion of Dr. Gray's work is very able, and we think all candid religious readers will find it conclusive. To all those timid souls who are worried about the progress of science, and the danger that it will subvert the foundations of their faith, and who perplex themselves with the question whether a Darwinian can be a Christian, we recommend the dispassionate perusal of this volume. The subject is touched upon in various aspects in the different papers; but the last article, which is newly contributed to the volume, grapples with the gravest difficulty of the case, and is an elaborate discussion of "Evolutionary Teleology," or the doctrine of purpose and design in Nature as affected by the principle of "Natural Selection." Dr. Gray maintains with great force that, instead of being subverted

by Darwinism, the doctrine of design is simply enlarged and seen to operate with a wider scope, and to stand upon a more comprehensive basis. He is by no means oblivious of the difficulties with which teleology is encompassed, and recognizes that it was the subject of powerful philosophical assault before Darwinism arose. But he sees also that the obstacles to the acceptance of the principle were due to the old ante-Darwinian views of the "Origin of Species." We can do no justice to this closely-reasoned essay by quotation from it, as it requires to be fully and carefully read to get a clear view of the author's position. A brief passage or two may, however, help to indicate it. Speaking of the contradiction involved in the old teleological interpretation of the origin of the organs and parts of living creatures, he says:

"The error, as we suppose, lies in the combination of the principle of design with the hypothesis of the immutability and isolated creation of species. The latter hypothesis, in its nature improbable, has, on scientific grounds, become so far improbable that few, even of the anti-Darwinian naturalists, now hold to it; and, whatever may once have been its religious claims, it is at present a hindrance rather than a help to any just and consistent teleology.

"By the adoption of the Darwinian hypothesis, or something like it, which we incline to favor, many of the difficulties are obviated, and others diminished. In the comprehensive and far-reaching teleology which may take the place of the former narrow conceptions, organs and even faculties, useless to the individual, find their explanation and reason of being. Either they have done service in the past or they may do service in the future. They may have been essentially useful in one way in a past species, and, though now functionless, they may be turned to useful account in some very different way hereafter. In botany several cases come to our mind which suggest such interpretation."

And again:

"Darwinian teleology has the special advantage of accounting for the imperfections and failures as well as for successes. It not only accounts for them, but turns them to practical account. It explains the seeming waste as being part and parcel of a great economical process. Without the competing multitude, no struggle for life; and, without this, no natural selection and survival of the fittest, no continuous adaptation to changing surroundings, no diversification and improvement, leading from lower up to higher and nobler forms. So the most puzzling things of all to the old-school teleologists are the *principia* of the Darwinian. In this system the forms and species, in all their variety, are not mere ends in themselves, but the whole a series of means and ends, in the contemplation of which we may obtain higher and more comprehensive, and perhaps worthier, as well as more consistent, views of design in Nature than heretofore. At least, it would appear that in Darwinian evolution we may have a theory that accords with if it does not explain the principal facts, and a teleology that is free from the common objections.

"But is it a teleology, or rather—to use the new-fangled term—a dysteleology? That depends upon how it is held. Darwinian evolution (whatever may be said of other kinds) is neither theistical nor non-theistical. Its relations to the question of design belong to the natural theologian, or, in the larger sense, to the philosopher. So long as the world lasts it will probably be open to any one to hold consistently, in the last resort, either of the two hypotheses, that of a divine mind or that of no divine mind. There is no way that we know of by which the alternative may be excluded. Viewed philosophically, the question only is, Which is the better supported hypothesis of the two?

"We have only to say that the Darwinian system, as we understand it, coincides well with the theistic view of Nature. It not only acknowledges purpose (in the *Contemporary Reviewer's* sense), but builds upon it; and if purpose in this sense does not of itself imply design, it is certainly compatible with it, and suggestive of it. Difficult as it may be to conceive and impossible to demonstrate design in a whole of which the series of parts appear to be contingent, the alternative may be yet more difficult and less satisfactory. If all Nature is of a piece—as modern physical philosophy insists—then it seems clear that design must in some way, and in some sense, pervade the system, or be wholly absent from it. Of the alternatives, the predication of design—special, general, or universal, as the case may be—is most natural to the mind; while the exclusion of it throughout, because some utilities may happen, many adaptations may be contingent results, and no organic maladaptations could continue, runs counter to such analogies as we have to guide us, and leads to a conclusion which few men ever rested in."

It may be added that Dr. Gray's volume is eminently readable, and, though dealing with "solid" subjects, is far from "heavy." The author has a great deal more humor about him than the student of his botanical manuals would be led to suspect. But the readers of "Darwiniana" will find that he is not only capable of fun, but has given it a pretty free vent in these pages. He seems half inclined to apologize for this, saying in his preface:

"If it be objected that some of these pages are written in a lightness of vein not quite congruous with the gravity of the subject and the

seriousness of its issues, the excuse must be that they were written with perfect freedom, most of them as anonymous contributions to popular journals, and that an argument may not be the less sound or an exposition less effective for being playful."

No apology, however, is needed, and it would be well if scientific writers having the capacity of humor would imitate the example of Dr. Gray in giving it freer expression in works designed for popular reading.

TRANSCENDENTALISM IN NEW ENGLAND: A HISTORY. By OCTAVIUS BROOKS FROTHINGHAM. G. P. Putnam's Sons. Pp. 395. Price, $2.50.

THE general purpose of the author in the preparation of this volume is thus happily stated by himself: "While we are gathering up for exhibition before other nations the results of a century of American life, with a purpose to show the issues thus far of our experiment in free institutions, it is fitting that some report should be made of the influences that have shaped the national mind, and determined in any important degree or respect its intellectual and moral character. A well-considered account of these influences would be of very great value to the student of history, the statesman, and philosopher, not merely as throwing light on our own social problem, but as illustrating the general law of human progress. This book is offered as a modest contribution to that knowledge."

The modern philosophic movement known as "transcendentalism," and the beginnings of which Mr. Frothingham traces to Germany, France, and England, has had a marked development in this country, and he has done a much-needed service to the students of the drifts and currents of modern thought by working out this historical delineation of it. No man was better prepared to do this useful work than Mr. Frothingham. By his wide, scholarly preparation, by his personal acquaintance with the leading characters who have had a share in it, by his sympathy with its influence, his observation of its results, and his attitude of an independant critic, he was qualified to deal with it on its various sides, and he has accordingly given us a book in a high degree readable and entertaining, instructive and valuable. Its merits as a study in philosophy are only equaled by the skill and attractiveness of its personal sketches of the men and women who have been prominent as representatives of transcendental thought. And, although Mr. Frothingham's reputation in the theological world will be regarded by many as dubious, yet his treatment of the historic bearings of transcendentalism upon religion is most suggestive, and may be read with profit by all interested in this class of questions.

THE LIFE AND LETTERS OF LORD MACAULAY. By G. OTTO TREVELYAN. Harper & Brothers. Vol. I., pp. 416; Vol. II., pp. 406. Price, $5.

THIS biography has made a decided and unexpected impression upon the public mind; it is, in fact, a sort of revelation. Of Macaulay's outer life as essayist, historian, orator, and politician, everything was known, his career having been a conspicuous one. But as to his private life little was known except that he was supposed to be haughty and cold, and an everlasting talker, who harangued the company at dinner until everybody was tired of him. Very little was understood of his kindly and loving nature, and his tender and heroic devotion to his father's family from youth to age, as so admirably narrated in these volumes. We have not in a long time been so enchained by a biographical work as by this of Mr. Trevelyan. We have not space to give any analysis of it, or to make extracts from its pages, but it is proper that we should refer to one feature in Macaulay's education which the reviews thus far seen quite fail to notice. Macaulay went to the University of Cambridge and took early and powerfully to the purely literary aspects of culture. The sciences and mathematics he despised, and hated, and ridiculed. But mathematics is the great thing at Cambridge. Macaulay might have neglected and abused the physical sciences to almost any extent, but if he had paid a decent respect to mathematics all would have been well. As it was, he incurred the disapprobation of the authorities, and failed to reach the position he sought, and to which he was unquestionably entitled by the brilliancy of his scholarship. It was exactly in the field where he was strongest that the ex-

aminers plucked him. They admitted that his translations from the Latin and Greek were faithfully rendered, but objected to his ungraceful, bald, and inornate English. The biographer adds: "The real cause was beyond all doubt his utter neglect of the special study of the place: a liberty which Cambridge seldom allows to be taken with impunity even by her most favored sons." Universities are very human, after all.

It is, however, noteworthy and very significant that Macaulay changed his views in regard to some of these matters in maturer life. Mr. Trevelyan says, "He used to profess deep and lasting regret for his early repugnance to scientific subjects." And well may he have done so, for the sciences in which he was deficient had not only a direct bearing upon his work as a statesman and an historian, but they were rising every decade into increasing prominence in the world of philosophic thought. Had Macaulay given to some of the modern sciences even a fraction of that untiring attention and insatiate interest which he devoted to almost every form of literary rubbish, it might have made a wide difference in the conservation of his fame.

THE LOGIC OF CHANCE. By J. VENN, M. A. New York: Macmillan. Pp. 500. Price, $3.75.

IN a work with the above title one is prepared to find most of the illustration and demonstration mathematical. This, however, is not the case with the present treatise, for the understanding of which no knowledge of mathematics is required beyond the simple rules of arithmetic. The author's object is, to show what are the foundations and province of the theory of probability, with especial reference to its logical bearings and its application to moral and social science—a matter of strictly philosophical inquiry, though the problems which are met with in the application of the rules of probability often require a profound acquaintance with mathematics. In the first part of his work the author lays down what he calls the "physical foundations of the science of probability." According to him, in those classes of things with which probability is concerned, the fundamental conception which we have to bear in mind is that of a *series*. The individual members of a *series* seem to be governed by no law; but when we consider the result of a long succession we find a marked distinction: a kind of order begins gradually to emerge, and at last assumes a distinct aspect. In the second chapter the author has an able critique on certain fundamental postulates of Quetelet's system.

Part II. treats of the logical superstructure erected upon these physical foundations, and we have chapters entitled "Gradations of Belief," "The Rules of Inference in Probability," "The Rule of Succession," "Induction," "Causation and Design," "Material and Formal Logic," "Modality," "Method of Least Squares," and "Fallacies." The third part is devoted to considering various applications of the theory of probability. The principle of life and property insurance is explained; also the laws governing games of chance. Finally, there are chapters on the "Application of Probability to Testimony," "Credibility of Extraordinary Stories," and "Statistics as applied to Human Actions."

GEOLOGICAL AND GEOGRAPHICAL SURVEY OF COLORADO AND ADJACENT TERRITORY. 1874. By F. V. HAYDEN. Pp. 515, with Maps and Plates. Washington: Government Printing-Office.

THE great amount of work performed by a United States Survey Expedition, during a field season, and the permanent value of such reports as that before us, will be understood from a brief statement of the method in which such surveys are conducted: 1. Such observations are made as will supply the data for a geological map, showing the distribution and extent of the formations which compose the surface of the region. A number of sections are examined, to ascertain how these formations lie upon one another, and to determine their relative ages and general paleontological relations. The extent and mode of occurrence of all economical products, as minerals, springs, etc., are noted, collections of rocks, fossils and the like, being made as far as possible. 2. The materials are collected for a map or representation of the surface features of the country, its streams, plains, mountains, cañons, etc.,

and this with all the accuracy that it is possible to give on a map of four miles to an inch, and in 200-foot contour-lines. Further, the general quality and distribution of timber, bottom, agricultural and unavailable lands are made the subject of investigation, while botanical, natural-history, and other specimens, are collected. The greater part of the volume treats of the geology, mineralogy, and mining industry of the region surveyed. Then there are separate reports on the Tertiary flora of the North American Lignitic, on ancient ruins in Southwestern Colorado, and on topography and geography.

VILLAGE COMMUNITIES IN THE EAST AND WEST. By SIR HENRY SUMNER MAINE. New York: Holt & Co. Pp. 425. Price, $3.50.

THE six lectures which give to this volume its leading title were first published in 1871, and have now reached a third edition. Their object is to trace the resemblances existing between the early stages of Western civilization and the existing status in many parts of India. Other scholars have shown the relations between modern European languages and the Sanskrit; the author's task is to point out the relations between the civil institutions of the East and West. Besides the lectures on village communities, the present volume contains sundry other papers, viz., one on the effects of observation of India on modern European thought, three addresses to the University of Calcutta, an essay on the theory of evidence, also one on Roman law and legal education.

COMMENCING with the July number, the *Penn Monthly* will hereafter be published for the Penn Monthly Association, by Jos. H. Coates & Co., Philadelphia. The editorship and ownership remain unchanged.

PUBLICATIONS RECEIVED.

Practical Botany. By A. Koehler, M. D. New York: Holt & Co. Pp. 410, with Plates. Price, $3.00.

Report of the Milwaukee School Commissioners (1875). Pp. 307.

Hay-Fever. By G. M. Beard, M. D. New York: Harpers. Pp. 266. Price, $2.00.

Theory of Medical Science. By W. R. Dunham, M. D. Boston: James Campbell. Pp. 150. Price, $1.25.

Giannetto. By Lady Margaret Magendie. New York: Holt. Pp. 180. Price, $1.25.

Archivos do Museu Nacional do Rio de Janeiro. Quarterly. Pp. 30. Rio de Janeiro: Imprensa Industrial.

Smithsonian Collection, viz., Specific Heats, Specific Gravities, Expansion by Heat. By F. W. Clarke, S. B.

Geographical Variation among North American Mammals. By J. A. Allen. Pp. 40. From Report of Hayden's Survey.

Thought: Its Struggles and Failures. By L. S. Benson. New York: Serial Science Society. Pp. 32. Price, 15 cents.

Centennial Poem. By Mrs. A. W. Duchow. Sonora, California: *Tuolumne Independent* print.

Mountain Surveying: A Nebula Photometer; Comparison of Prismatic and Diffraction Spectra. By Prof. E. C. Pickering. From *American Journal of Science* and "Proceedings of the American Academy."

Determination of Baryum. By P. Schweitzer, Ph. D. Jefferson City: Regan & Carter. Pp. 36.

Report on Dermatology. By L. P. Yandell, Jr., M. D. Indianapolis: *Journal* print. Pp. 7.

Centres of Ancient Civilization in Central America. By Dr. C. H. Berendt. New York: D. Taylor, printer. Pp. 14.

Geometrical Chemistry. By H. Wurtz. New York: J. F. Trow & Son, printers. Pp. 73.

Journal of the American Society of Civil Engineers. May. Pp. 70.

Transactions of the Kansas Horticultural Society (1875). Topeka: Martin, printer. Pp. 267.

Some Disputed Points in Physiological Optics. By H. Hartshorne. Pp. 12.

MISCELLANY.

The Cruise of the "Challenger."—*Nature*, for June 1st, gives an exceedingly interesting account of the voyage round the world recently completed by the Challenger. This voyage was undertaken chiefly for scientific purposes, the principal object being to "determine as far as possible the physical and biological conditions of the great ocean-basins of the Atlantic, the Southern Sea, and Pacific."

Important discoveries made during recent expeditions on the European border of the Atlantic and in the Mediterranean, by Dr. Carpenter, Mr. Gwyn Jeffries, and Prof. Wyville Thomson, stimulated a desire for further investigation, and this great voyage under direction of Prof. Thompson, as chief of the civilian staff, was inaugurated and carried through to a successful issue.

The ship left England on December 21, 1872, and returned to Spithead on May 24, 1876, having been absent a little less than three and a half years, and making a voyage of nearly 69,000 miles.

During this voyage 362 observing-stations were established, at each of which the depth and bottom temperature of the ocean were ascertained, and samples of the water, mud, and animals of the bottom, brought up for examination.

The direction and rate of currents were carefully studied, and "serial soundings" were made with special instruments to determine the temperatures at different depths. Upward of 50,000 meteorological observations were made during the first twelve months of the cruise.

The regular work of the expedition began at Teneriffe, from which point a line of soundings was carried across the Atlantic to the small island of Sombrero, a distance of 2,700 miles.

At 1,100 miles from Teneriffe, and 1,600 miles from Sombrero, bottom was found at 3,150 fathoms, which consisted of "perfectly smooth red clay, with scarcely a trace of organic matter," but at depths of only 2,200 fathoms the bottom was one mass of calcareous shells of foraminifera.

The red clay was found to be almost pure clay and a red oxide of iron with some manganese. This material is supposed by Prof. Thomson to be the residue or ash from decomposition of the shells. Experiments were made by Mr. Buchanan, of the staff of scientists, confirming this conclusion. He subjected globigerina ooze to the action of a weak acid, and found that after the carbonate of lime was removed there remained about one per cent. of a reddish mud, consisting of silica and alumina, and a red oxide of iron.

The globigerina shells were abundant at depths not exceeding 2,200 fathoms, but at greater depths a gray ooze occurred, the shells being in a state of decomposition; in deeper parts this disappeared, leaving the residuum of red clay.

This clay was found to be widely distributed in both the Atlantic and Pacific Oceans, and in many places contained concretions of the peroxide of manganese.

The specific gravity of ocean-water was carefully tested by Mr. Buchanan, and very unexpected results were obtained. The notion that the specific gravity increases with increase of depth seems unfounded, as it was ascertained to be greatest near the surface, diminishing to a depth of about 500 fathoms. From this downward it is nearly uniform.

Dredgings at great depths usually brought to the surface living organisms. At 3,150 fathoms (upward of three and a half miles) on the Atlantic cruise, only foraminifera were found, but other organisms were abundant at similar depths elsewhere.

By the serial temperatures taken in several places, it is evident that conditions exist which may greatly modify the distribution of the deep-sea fauna. Near Raine Island, not far from the entrance to Torres Straits, there was found at 2,650 fathoms, with bottom of red clay, a temperature of 35° Fahr. But it was also found that the same temperature occurred at a depth of only 1,300 fathoms. Here, then, the waters through 1,350 fathoms of depth, were of a uniform temperature. Over a wide area similar results were obtained, and the conclusion is, that this area, known as the Melanesian Sea, is so surrounded by a reef, rising to within 1,300 fathoms of the surface, that free communication of its waters with the outside ocean is prevented.

Animal life was found to be scarce in

this sea, but sufficient to show that it is "possible in the still bottom water, although such conditions in the Mediterranean do not seem to favor life."

The deepest water was found on the line from Admiralty Islands to Japan, one sounding giving the enormous depth of 4,575 fathoms, or five and a half miles. This is said to be the deepest trustworthy sounding yet made, excepting two by the Tuscarora off the east coast of Japan, where a depth 600 feet greater was found.

One of the results of this expedition has been to extend a knowledge of the fauna of the deep oceans, and the forthcoming work of Prof. Thomson will be brilliant with illustrations of new and beautiful forms.

The great voyage is divided into four sections. The first is from Sheerness, England, to the Cape of Good Hope, but by the very roundabout course of St. Thomas, Bermuda, Halifax, and St. Vincent. The second section is from the Cape of Good Hope to Hong-Kong by the way of Australia and the Polynesian Islands. The third section is from Hong-Kong to Valparaiso, touching at Japan, the Sandwich Islands, Tahiti, and Juan Fernandez. The fourth section is from Valparaiso to Sheerness, arriving on the 26th of May last.

Recently-Discovered Fossils.—In an appendix to the *American Journal of Science* for June, Prof. O. C. Marsh gives notices of a new sub-order of Pterosaurians, *Pteranodontia*, and of three new species of *Odontornithes*. The distinctive feature of the sub-order *Pteranodontia* is the *absence of teeth* (hence the name). The new genus *Pteranodon* is readily distinguished from any pterodactyls hitherto described by the cranial characters, which are well shown in a nearly perfect skull and portions of others in the Yale Museum. The cranium is very large, and the facial portion greatly elongated. There is a high sagittal crest which projects backward some distance beyond the occipital condyle. The maxillary bones are closely coössified with the premaxillary, and the whole forms a long, slender beak. There are no teeth or sockets for teeth in any part of the upper jaws, and the premaxillary shows some indications of having been incased in a horny covering. The lower jaws also are long and pointed in front, and entirely edentulous. In several other respects the jaws in this genus are more like those of birds than of any known reptiles.

From the same localities, and from the same geological horizon, the Upper Cretaceous of Western Kansas, which have yielded the specimens constituting the sub-order of edentulous Pterosaurians, come the remains of the *Odontornithes*, or birds with teeth, and the two doubtless lived together in the same region. The remains of one of these birds with teeth indicate a bird fully six feet in length from the apex of the bill to the end of the toes. The femur and the tibia resemble those of some modern diving-birds, but the toes are shorter and stouter.

The Prehistoric Pig.—In an essay on "The Prehistoric Pig of Britain," Prof. Rolleston arrives at the following conclusions: 1. The domesticated pig of pre-Roman times he refers to the wild variety of *Sus scrofa*. 2. The Indian wild-hog (*S. cristatus*) differs mainly by the retention of structural conformations which are only temporarily respresented in the European wild species. 3. Taking the changes which domestication produces into account, *S. Indicus* he conceives to be a modified *S. cristatus*, and not derived from *S. leucomystax*, or other species. 4. The skull of a wild-sow from the alluvium at Oxford possesses such a combination of characters as to cause the author to hesitate in accepting the Torfschwein (*S. scrofa*), variety *palustris* of Rütimeyer, as a distinct species. 5. Simplicity of third molars in a large skull of the Bornean pig (*S. barbatus*) has no value. 6. The *S. verrucosus*, in its tear and cheek bones, differs from the *S. barbatus*, and these peculiarities obtained in the old Irish "greyhound pig" figured by Richardson.

Appropriation of Silica by Plants.—Prof. P. B. Wilson, of Washington University, Baltimore, having, in a chemical examination of the ash of grasses, discovered that the silica contained in such ash differs essentially from silica reduced from natural silicates—that, in fact, it had been assimi-

lated by the plant in the free state—determined to apply infusorial earth to land sown in wheat, and afterward with the microscope to search for the siliceous shields of diatomaceæ in the straw. Of course, if these were to be found occurring in the plant with the same forms which they have in the infusorial earth, it is plain that they must have been taken up by the plant and distributed through its system unaltered. The event fully justified this conclusion. The straw having been treated with nitric acid, the siliceous residuum was placed on the field of the microscope, and was seen to consist wholly of the siliceous shields of diatomaceæ, the same as found in the infusorial earth, excepting that the larger disks in their perfect form were absent—evidently because these disks were not sufficiently minute to enter the root-capillaries. The result of these investigations shows the necessity of finely-divided silica in the soil; also, that simple or compound silicates are useless as fertilizing agents.

Forestry.—The first of a series of papers on "European and American Forestry," now appearing in the *Penn Monthly*, contains a brief history of "Deforestation," or devastation of forests, in the Old World. The subject is one that nearly concerns the inhabitants of the United States, where the process of deforestation advances with unparalleled rapidity. Among the many instances quoted by the author of the evils consequent on the denudation of woodlands is that of Sicily, once the granary of Rome, now almost a waste from the effects of forest devastation. The island has scarcely a stream that lasts through the summer, and few perennial springs. The soil has suffered deplorably for want of sufficient irrigation. Greece, in common with Asia Minor, has been shorn of its original forests, and its characteristic feature is represented in steppes and unproductive barren wastes. Of Spain it may be said that at one time one-fifth of its surface was forest; now the proportion is only nine per cent. In different portions of the country noble forests still exist; but, on the whole, the destruction of the useful woods has been indiscriminate and improvident, and Spain, like all other countries, has suffered under the abuse of that universal law according to which soil and climate depend on the extent of forest-land.

Air-Bags for raising Ships.—Prof St. Claire, of Edinburgh University, in 1785 proposed the use of air-bags for the purpose of raising sunken ships. In 1864 air-bags were first practically applied for raising a steamer sunk in the lake of Boden; in this case the bags, owing to some defect, gave way. The Alexandrovsky system, perfected some ten years ago, has already rendered good service to the Government and commerce of Russia on several occasions. The bags adopted in the Russian Navy, as we learn from *Engineering*, are, when inflated, of cylindrical form, measuring twelve feet in diameter and twenty feet in length. They are composed of three layers of the thickest canvas saturated with India-rubber. Their lifting power averages sixty tons. In order to lift a vessel, several chains are drawn by divers under her bottom, and air-bags attached to the ends of each of them as near the ship's bottom as possible: the bags, being inflated by means of air-pumps, cause the ship to rise. Before pumping air into the bags, all the chains are connected in a transverse direction, so as to form one system, thus preventing the pairs of bags from sliding off from beneath the hull of the ship. As the vessel rises the surrounding water-pressure decreases, and the excess of air passes out through safety-valves.

Night-Habits of Fish.—Mr. W. Saville Kent had in the Manchester Aquarium a number of young herrings, which were so tame as readily to take their prepared food from the hand of a keeper. But a large number of the fishes were found dead each morning, a fact which seemed inexplicable, considering their quiet behavior during the day. A night inspection, however, revealed the cause of this rapid destruction. It was found that the nocturnal movements of the herring, at least in confinement, are altogether different from their movements in daylight. In the latter case, these movements are quiet and uniform, the fish swimming around their tank in one shoal and one continuous stream. At night,

on the contrary, the shoal is entirely broken up, each fish taking an independent path, and darting from one side of the tank to the other with surprising agility. It was during these active nocturnal movements that the fish struck against the rockwork of the tank and came to an untimely end; this mortality, however, was soon arrested by placing a dim light over their tank, which illuminated the outline of the rockwork just sufficiently to enable them to recognize and avoid it. With this dim light the fish still retained their active habits, and it was noticeable that during these night-hours they were more than ordinarily alert for food, dashing vigorously at any entomostracan or other minute organism that passed through the water. This circumstance would seem to explain why "drift-net" fishing for herrings can be carried on successfully only at night, that being the time when the fish rise to the surface of the water to feed on the innumerable organisms that there abound.

Prof. Mayer on Sound.—Prof. Mayer, of the Stevens Institute of Technology, read at the late meeting of the Academy of Sciences a paper on the "Sensations produced by Concurrent and Rapidly-succeeding Sounds," a synopsis of which appears in the *Tribune*. The author showed how certain sounds extinguish the sensation of other sounds. The rule appears to be that, while low sounds cannot extinguish high ones, high sounds may obliterate low ones. He had been led to this course of observation by noticing that the click of a noisy clock was, at certain intervals, silenced if a watch was held to the ear. These intervals of silence, he ascertained, occurred when the sharp tick of the watch and the low click of the clock were simultaneous. Then by various and elaborate devices he satisfied himself, not only of the general fact, but as to what balancing of intensities was requisite. Prof. Mayer proceeded to demonstrate the application of the rule to musical sounds. This he made plain to the Academy by means of apparatus producing a certain low note from a wind-instrument simultaneously with the same note several octaves higher and of greater intensity. The high note killed, so to speak, the low one. But, on the other hand, a low note of great intensity was powerless to extinguish a faint high note: the high note utterly refused to be drowned by any volume of the lower sound.

Ancient Condition of Great Salt Lake.—According to Prof. G. K. Gilbert, of Wheeler's Expedition, the Great Salt Lake of Utah anciently had an outlet northward, the overflow being carried to the ocean by the Columbia River. But the Great Salt Lake was then a great inland sea, as is evidenced by the existence of an ancient beach 970 feet higher than the Great Salt Lake of to-day, and 700 feet higher than Sevier Lake. The subsequent changes of level are described as follows by Prof. Gilbert in the *American Journal of Science:* "From the upper beach the water slowly subsided by desiccation, recording its lingerings in a series of fainter shore-lines. When it had fallen to the level of the divide between the Sevier and Salt Lake Basins, it was separated into two unequal portions. In one of these the evaporation exceeded the inflow from rivers, and the subsidence continued; in the other the inflow exceeded the evaporation, and the surplus was discharged over the divide into the former portion, just as the surplus of Utah Lake is now discharged into Great Salt Lake. In the course of time, as the climate became drier, this overflow ceased, but not until it had carved a channel of some magnitude. This channel is crossed by the old overland stage-route, and is known as the Old River-Bed." It is the opinion of Prof. Gilbert that the humid climate which was marked by this inundation of Utah was preceded by one as arid as the present, and that the humidity was a phenomenon of the Glacial epoch. A fuller statement and discussion of the facts will appear in the forthcoming geological volume of the "Reports of Wheeler's Surveys."

Spontaneous Hypnotism.—A case of spontaneous hypnotism is described by Dr. Bouchut in *Les Mondes*. A little girl of ten had been apprenticed five months to the business of making waistcoats. One day, after a month of steady but not excessive work, and while sewing a button-hole, she became unconscious and slept for one hour. On awaking, she resumed her work, but with the same result. This hypnotism did

not occur with any other kind of sewing. The case having now come under the notice of M. Bouchut, he gave the girl a buttonhole to sew. She had hardly sewn three stitches when she sank from her chair on the ground, and fell fast asleep. M. Bouchut raised her up, and noted catalepsy of the arms and legs, dilatation of the pupil, slowness of pulse, and complete insensibility. She slept for three hours. Next day he made a similar experiment, when the girl slept only one hour. While no other kind of sewing could affect the girl in this way, M. Bouchut found that he could produce hypnotism by causing her to look intently on a silver pencil held at the distance of ten centimetres from the root of her nose. The case evidently was one of Braid's hypnotism, only occurring spontaneously, and not brought on by way of experiment.

Periodic Movements of the Foliage of Plants.—The *Abies Nordmanniana*, a coniferous tree now widely diffused on account of the elegant coloration of its leaves, appears to bear uniformly whitish foliage, when observed in the morning or toward evening, but when observed in the middle of the day the green tint seems general. The reason of this difference is found in the fact that the position of the leaves on the branch is different in the daytime from what it is at night; in the former case the leaves are spread out upon the branch and present their upper surface, producing the greenish aspect of the foliage; during the latter period, on the contrary, it is the lower or whitish surface that is presented to the observer. Thus there is a diurnal and a nocturnal position. As the day declines, the leaves, which at noon were horizontal, are seen gradually to erect themselves upon the branch, often becoming nearly perpendicular to it, and this movement of erection is accompanied by a movement of torsion in the basal part of the leaf, often traversing an arc of 90°.

Treatment of Lunatics by Colored Light.—Medical journals give an account of experiments recently made by Dr. Ponza, director of the lunatic asylum at Alessandria, Piedmont, to determine the influence of the solar rays on brain-diseases. Dr. Ponza, having communicated his views to Father Secchi, was encouraged to study the subject. In his letter to Dr. Ponza, the Roman astronomer expressed the opinion that the violet rays are of special importance. "Violet," he writes, "has something melancholy and depressive about it; perhaps violet light may calm the nervous excitement of maniacs." He then advises Dr. Ponza to perform his experiments in rooms with stained-glass windows, and with the walls painted of the same color as the glass panes. One patient, who had been affected with morbid taciturnity, became gay and affable after spending three hours in a red chamber; another, a maniac who refused all food, asked for breakfast after having staid twenty-four hours in the same red chamber. In a blue chamber a highly-excited madman became calm in one hour. A patient was made to pass the night in a violet chamber; on the following day he felt himself cured, and has been very well ever since.

Unhealthy Trades.—Among the lectures delivered by Dr. Richardson before the London Society of Arts, on "Unhealthy Trades," is one devoted to the "Industrial Diseases of Workers in Earthenware." He shows from the official statistics that potters are among the three sections of the population of England who represent the lowest vitality. The males of fifteen years and upward die at the rate of 38 per cent. above the males of all ages; and the commencement of this increased mortality is at the period when the men are approaching their prime of life, namely, at thirty-five years, and it extends onward to the end of life. Thus where in the general population 100 males of thirty-five years die, a proportion equal to 154 potters dies. For the four subsequent increments, namely, forty-five, fifty-five, sixty-five, and seventy-five years, for 100 deaths in the general male population, the deaths among male potters are proportionately 182, 181, 192, 141. The wages of the potters are good, and the labor not physically severe on healthy, fully-developed persons. The special diseases incident to this kind of employment are bronchitis with "potter's asthma," pulmonary consumption, and lead-paralysis. Subsidiary to these are rheumatic affections and affections of the stomach. The special causes of disease

are: variations of heat and cold, and constant inhalation of dust; these causes produce chronic bronchitis and asthma. The paralytic diseases are induced by lead; of these diseases the victims are the dippers and the women who assist them. "Could we," remarks Dr. Richardson, in conclusion, "relieve the earthenware manufacturers from the two grand causes of disease to which they are exposed, dust and lead, though some generations would be required in order to restore them, as a community, to perfect vitality, there is no reason why their death-rate should not, at once, be reduced to at least half its present excess, and the steady progress of their vital regeneration be immediately commenced."

Effects of Cold on Milk.—The effect of cold upon milk has been made a subject of experiment by M. Eugène Tisserand, who finds that if cow's milk is immediately, or soon after being drawn, placed in vessels at various temperatures between freezing-point and 90° Fahr., and the initial temperature maintained for twenty-four or thirty-six hours, the nearer the temperature of the milk is to freezing-point the more rapid is the collection of cream, the more considerable is the quantity of cream, the amount of butter is greater, and the skimmed milk, the butter, and the cheese, are of better quality. These facts, he believes, may be explained by Pasteur's observations on ferments. It is probable that the refrigeration arrests the development of living organisms and hinders the changes due to their growth. The facts stated indicate room for great improvement in the methods of storage and preservation of milk. To keep milk at its original quality, extreme cleanliness and a low temperature are absolutely necessary. In the north of Europe the value of cold is already recognized, and in warmer climates the need of its assistance is greater.

Coal-Gas as a Fuel.—The use of coal-gas in the place of gross fuel for the purposes of heating and cooking is rapidly coming into public favor in England. In this country the high price of gas is doubtless the principal reason why this most convenient form of fuel has not been more widely adopted, in the place of coal. The advantages of gas are manifold, and are clearly set forth in a paper read by Mr. John Wallace at a meeting of the London Society for the Promotion of Scientific Industry. First, we can absolutely control the amount of gas consumed and the degree of heat produced. In cooking, this control of the degree of heat is of the utmost importance: too quick or too slow a fire must result in bad cooking. Now, the heat of a coal-fire is very irregular, and is liable to be affected by so many circumstances that constant attention is required to keep it in the proper condition for delicate operations. Then, in point of cleanliness and facility of application, gas-stoves are far superior to coal-stoves. "The increasing cost of household labor," adds Mr. Wallace, "renders it highly probable that the same measure of success awaits the domestic application of gas as has already established the sewing-machine among our household gods. It is to be hoped that among the numberless schemes of gas-manufacture which have recently been made public we may soon be provided with a gas which shall be sufficiently cheap and plentiful to be used not only for lighting and heating in private dwellings, but also for trade and manufacturing purposes in workshop and warehouse."

Toxic Action of Putrid Blood.—The influence of various conditions upon the toxic property of blood has been investigated by V. Feltz, whose results, as communicated to the Paris Academy of Sciences, are briefly stated in the *Lancet*. He first determined the effects on a healthy dog. The injection of from one to three cubic centimetres caused all the symptoms of intense blood-poisoning in from three to eight days. Exposure to the air for periods of 24 to 96 hours made no difference in the toxic properties of the blood; exposure to compressed air for 24 to 144 hours was also without effect. Exposure to oxygen had different results, according to the time of exposure. Contact with oxygen for from 6 to 72 hours had no effect. Animals injected with blood which had been exposed to oxygen for 96 to 216 hours recovered after five or six days' illness. The result was the same with blood through which a continuous stream of oxygen was passed. A very similar effect was

produced by exposure of the blood to a vacuum for many hours. A second series of experiments was to determine the influence of time on poisonous material. When the putrefied blood was kept so long that no living bodies could be discovered in it by microscopical examination, the same toxic effects were produced by its injection, but were less intense. Putrefied blood was then dried by slow exposure to the air, powdered, mixed with distilled water, and injected. The effects were not, as in the other cases, immediately manifest. After four to six days of incubation, the animals became ill; some died, others recovered. M. Feltz concludes that, as exposure to a vacuum and desiccation did not remove the toxic agent, it cannot be a gas; that activity on the part of the minute moving particles within it is not necessary for its septic effect; and that the development of bacteria, etc., in the blood of the animals injected, points to the germs of those bacteria as being the probable efficient means of the production of the poisonous effects.

Ostrich-Farming.—Ostrich-farming has within the past few years attained a remarkable development in South Africa. We present to our readers a few notes upon this new industry, taken from an address by Mr. P. L. Simmonds before the London Society of Arts. The climate in all parts of the Cape Colony is said to be alike favorable to the growth and production of the ostrich, and there are but few districts of the colony where this industry is not carried on. Mr. A. Douglas, of Hilton, appears to have been the first systematic breeder of ostriches in the Cape Colony. About eight years ago he bought a pair of birds, and subsequently added four more, making in all two cocks and four hens. By means of an incubator he succeeded in raising from these six birds 130 young ostriches in one season. The ostrich-farm of Mr. Kinnear, of West Beaufort, consists of eight acres of land, inclosed with fences. In this inclosure, which is sown with lucern, thirty ostriches are kept. There are two methods of obtaining the feathers, plucking them, and cutting them a little above the roots, which are removed two months afterward. Mr. Kinnear prefers the latter mode. The first plucking takes place when the bird is about eight months old, but the feathers are then not of much value. The operation is renewed every eight months. Three pluckings of birds in full plumage realized to Mr. Kinnear £240, or £120 per annum, that is, £8 per bird.

In the wild state, five female ostriches are often attached to one male, and they all lay their eggs in one nest, and sit on them in turn. Mr. Kinnear, however, only assigns one female to each male. They are coupled in July (the second month of winter), and commence laying in August, and continue laying for about six weeks, after which they sit till October. A month or six weeks later, they recommence to lay for about five weeks, provided the young brood are removed. In forming the nest—a large hole scraped in the sand—the male bird is most assiduous, and when all is ready the laying of the eggs commences. From fifteen to twenty eggs are laid and carefully arranged in the nest. The male bird usually sits by night, the female morning and evening; in the wild state the birds frequently leave the nest untended during the heat of the day.

Ostriches are, comparatively, inexpensive to keep, as during three-fourths of the year they require only a little artificial food, the grass produced on the farm being nearly sufficient for their maintenance; during the remaining fourth, they only need some supplemental supplies of green food, with a little Indian-corn. Each ostrich eats about twenty pounds of lucern a day.

Culture of the Cochineal Cactus.—The culture of the cochineal cactus was introduced into the Canary Islands in 1840. This plant, as indicated by its name, is the favorite food of the cochineal insect, whose body furnishes the well-known dyestuff cochineal. The culture developed rapidly, still for some years the supply of cochineal fell short of the demand. In 1848 prices varied from eleven to twelve francs per pound Spanish, the cost of production not exceeding 25 per cent. of this sum. A "cochineal mania" was the result, and all other crops had to give way before cochineal. Prices began to fall under the influence of this excessive production, and from 1860 to 1870 the cochineal sold for

five to six francs, and there has been a steady decline ever since. In 1870 the price was four francs, in 1871 3.50 francs, in 1872 three francs, in 1873 2.50 francs. There is now a very general disposition to abandon this culture, and since 1872 the amount produced has been growing less from year to year. This decline is also, in a great measure, due to the introduction of new dyestuffs of mineral origin.

Detection of Arsenic in Organic Matter.—Dr. Armand Gautier proposes a new method for separating arsenic from animal matters, and for detecting its presence. By combining the sulphuric-acid and the nitric-acid processes he has obtained very satisfactory results, as regards both the rapidity of the operation and the exactness of the determinations. He first treats the matter supposed to contain arsenic with nitric acid, then with sulphuric acid, and finally with nitric acid again. By the first operation the organic substances are disaggregated; by the second they are destroyed very rapidly, and by the third, with the addition of more nitric acid, the last traces of organic matter are eliminated, while the formation of sulphide of arsenic is prevented. Having made a number of quantitative experiments, M. Gautier never met with a discrepancy amounting to so much as one-tenth of a milligramme between the amount of arsenic introduced and that found.

Timidity of Birds.—Dr. J. G. Cooper, in the *Naturalist*, comments on the "sociable and confiding disposition" of the birds of the Western United States, compared with the same species eastward. This difference, he remarks, has been noticed by several writers, but the reasons have so far been scarcely mentioned. According to the author, the chief reason is that in the West bird-collectors and idle boys are less numerous, while sportsmen find larger game so plenty that they do not waste ammunition on small birds. Besides this, the prevalence of prairies over most of the Western region makes any garden full of trees and shrubs a rare nursery for the woodland species, where they find more protection from hawks and weasels than in their native groves, while they may also levy a small contribution on the fruits in return for the insects they destroy, and their lively songs. In California, the poison intended for ground-squirrels has also destroyed millions of birds about the fields, and left them unhurt in gardens.

Fattening Oysters.—Salt oysters, on being transferred to fresh water, are "fattened" in the course of two or three days; if allowed to remain longer they become lean again, and are flavorless. Prof. Persifor Frazer, of the Academy of Natural Sciences of Philadelphia, holds that this change cannot be due to an increase of flesh, and attributes it rather to a simple distention of the tissues, owing to the admission into them of a greater quantity of fluid. During the oyster's period of growth on the sea-coast, its tissues are constantly saturated with the ocean-brine; on removing the animal to merely brackish or to fresh water, the conditions are at once favorable for osmose to be commenced. The fresher and less dense liquid without permeates inward more rapidly than the more saline and denser liquids within escape, and the effect is to swell the tissue, as a cow's bladder half filled with air and immersed in a vessel of hydrogen is swollen, or still more nearly like the swelling of a bladder half filled with copper sulphate when immersed in water. "It is worth while to inquire," adds Prof. Frazer, "whether means could not be devised to effect this fattening while yet not depriving the oyster of the salty flavor which is its chief charm to many consumers. Perhaps an immersion in concentrated brine for several days and its subsequent removal to ocean-water would suffice."

"Shooting-Stars."—We make a few selections from an interesting paper on "Shooting-Stars," by Prof. C. A. Young, published in the *Boston Journal of Chemistry*. These shooting-stars, he says, are very small, for the most part weighing certainly not more than a few grains, and possibly only some thousandths of a grain—mere particles or cloudlets of dust, which are traveling in space under the same laws as those which govern the motions of the planets and comets, and with a velocity as great. Their least velocity is more than thirty times that of a cannon-ball. When they encounter

our atmosphere, this velocity is destroyed by the resistance, and, according to well-known laws, their energy of motion is converted into heat of intensity sufficient to render them incandescent, and even to dissipate any solid portions in vapor. Their numbers are very great. About forty per hour is a fair average for one station, or nearly one thousand each day. If the calculation is carried out for the whole earth, allowing that at each station all are observed which come within a circle two hundred miles in diameter, the total number reaching the earth daily is found to be about five million; indeed, Prof. Newton, who is perhaps the highest authority on this subject, sets the number still higher, at seven and a half million. A curious fact is, that the hourly numbers increase from sunset to sunrise by some fifty per cent. The reason is simply that in the evening we are, so to speak, behind the earth as it rushes through space, and see only those which overtake us; in the morning, on the other hand, we are in front, and see all we meet, as well as those we overtake.

The most remarkable discovery of recent times in respect to these bodies remains to be mentioned. It is found that in four well-marked cases the orbits of important meteoric swarms coincide exactly with the orbits of well-known comets; that the swarm of meteors follows in the wake of the comet and is somehow connected with it. The discovery dates from 1866, when Schiapparelli first proved the connection between the Leonids (November meteors) and Temple's comet. Since then the same thing has been shown of the Perseids, Lyrids, and Bielids.

Cause of the Aurora.—According to Groneman's hypothesis, an account of which is given in the *Academy*, there are streams of minute iron particles circulating around the sun like the well-known meteor-streams, and these, when they come near the earth, are attracted by its poles, and form filaments stretching out into space, in the same way as iron-filings, sprinkled on paper, arrange themselves in lines under the influence of a magnet underneath, each particle attracting the next by virtue of its induced magnetism. Groneman refers the phenomenon of the aurora to the ignition of this cosmical iron-dust in its passage through air, the distinction between this and an ordinary meteor-shower being that, on account of the filamentous arrangement of the particles in the direction of the dipping needle, streamers are formed, which by an effect of perspective appear to radiate from a point in that direction, and therefore nearly overhead. It is necessary to suppose that this meteor-stream is traveling nearly in the same direction as the earth, and Groneman enters into elaborate calculations to show that the velocity of the particles would not be too great to permit the magnetic attraction to form filaments of 200 miles in length.

Dr. Roberts on Spontaneous Generation.—Dr. William Roberts, of Owens College, Manchester, whose experiments were quoted by Dr. Bastian, in a recent communication, as favoring the doctrine of the spontaneous generation of bacteria, contradicts this interpretation of the results of his investigations. "On the contrary," writes Dr. Roberts, "the weight of my experiments is entirely against him" (Bastian), "and in favor of Pasteur's conclusions. It appears to me," he adds, "that the attitude of Dr. Bastian on the question of the origin of bacteria arises from what I may call the inverted significance which he attaches to the two contrasted results—barrenness or fertility—which follow after boiling an organic infusion. Throughout the controversy Dr. Bastian speaks of the barren tubes and flasks as 'failures,' or 'negative results;' and he evidently regards the fertile tubes and flasks as 'successful' experiments, having the force and authority of 'positive' results. The true view is just the reverse of this: it is the barren flask that has the character of a positive result. For what does the experimenter set himself to do in these experiments? He seeks to destroy, by boiling, all preëxisting bacteria in these infusions, and to leave unimpaired their powers of promoting the growth of bacteria. And it is found, in fact, that this latter quality is perfectly preserved in boiled infusions; for they breed bacteria with the utmost luxuriance when they are reinfected from an extraneous source. . . . When I take up one of the flasks or bulbs which have remained barren in my chamber for

three or four years, though supplied with air (filtered through cotton-wool) and suitable heat, my wonder never ceases. Each one is a new experiment, every day repeated, and multiplied indefinitely; day after day I ask myself, 'Why does it not germinate?' I compare it to a field in spring not yet sown, but ready for the reception of the seed: for if I withdraw the plug of cotton-wool and admit the dust of the air, or introduce a drop of water, all is changed; in a few hours the stillness of years gives place to life and activity. I repeat, it is the fertile flask, and not the barren flask, that wears the complexion of a failure and of a negative result."

NOTES.

THE American Association for the Advancement of Science meets this year at Buffalo, the sessions commencing August 23d. William B. Rogers, of Boston, is President; Charles A. Young, Dartmouth College, Vice-President Section A; E. S. Morse, Salem, Mass., Vice-President Section B; Thomas Mendenhall, Columbus, Ohio, General Secretary.

THE Entomological Club of the American Association for the Advancement of Science will meet at Buffalo, N. Y., on the 22d of August, in quarters provided by the local committee of the Association. All interested in the subject of entomology are invited to attend, and to repair at first to the Tifft House for instructions.

THE French Association for the Advancement of Science will hold its meetings this year at Clermont-Ferrand, commencing August 17th. The President of the Association is M. Dumas, of the Académie des Sciences.

THE Agassiz Museum at Cambridge, Mass., has passed from the hands of the special board of trustees, and is now the property of Harvard College. Besides the real and personal property of the museum, the college comes into the possession of $115,000 in money, as also over $310,000 constituting the "Agassiz Memorial Fund."

THE General Council of the British Association has fixed Wednesday, September 6th, as the date of opening this year's sessions. The place of meeting is the city of Glasgow. The authorities of the Glasgow University have tendered to the Association the free use of the commodious buildings situated in the western district of the city. A guarantee fund of £4,000 will be raised by the citizens of Glasgow; of this sum the city corporation gives £500. Sir R. Christison, who was elected President last year, has resigned on account of ill-health, and Dr. Andrews, Vice-President of Queen's College, Belfast, has been elected in his place.

A CORRESPONDENT sends us an account of the passage of a brilliant meteor, unusually large and bright, over Northern Indiana, Northern Ohio, and Southwestern Michigan, on the evening of July 8th, at precisely nine o'clock. An observer at Elkhart, Indiana, says at that place it seemed almost exactly overhead, and its course began very near 61 Cygni, and ended about 5° south of Ursa Minor. The illumination was as bright as that of a full moon, and was of a greenish-yellow light. The whole pathway was visible for fifteen minutes, and for half an hour a bright, hazy spot, about 6° long and 3° wide, could be seen near the middle of the pathway. No sound accompanied the movement of the flaming body, and at last it disappeared in a sort of bluish light, very brilliant at first, but growing hazy, and finally disappearing. Judging from its height, if it descended to earth at all it must have fallen into Lake Michigan. The course of the body was as straight as an arrow, but its fiery trail very soon assumed the serpentine appearance that would naturally be caused by the atmospheric currents.

DIED, recently, in London, at the age of seventy-five years, Edward Newman, F. L. S., F. Z. S., editor of the *Zoölogist* and the *Entomologist*, two serial publications which have attained considerable success among amateurs of entomology and natural history in England.

THREE years ago there was founded at Boston a "Society to encourage Studies at Home." The number of students who received encouragement from the Society during the first year of its existence was 45, the second year 82, the third year 298. In making choice of studies to be pursued, 127 selected history, 118 English literature, 44 science, 36 art, 19 German, and 16 French.

PROF. C. WYVILLE THOMSON, director of the scientific staff of the Challenger, has received the honor of knighthood from Queen Victoria.

A PIECE of telegraph-cable, the rubber covering of which had been pierced by grass, was exhibited at a meeting of the Bengal Asiatic Society; the efficiency of the cable was thus destroyed. The species of the grass, owing to its dried-up condition, could not be determined. It was suggested, as a probable explanation, that the

seeds had become attached to the core when under water, and had afterward germinated when the core was stored.

PROF. BRUDENELL CARTER, in an address on the "Relations of Ophthalmology to General Surgery," takes the ground that, while the growth of specialism in this department has given us improved operations and more dexterous operators, it has retarded investigation by diminishing the number of laborers in the field, and the opportunities of those laborers to study the facts from the standpoint of general pathology.

AN Italian chemist, A. Casali, obtains a green pigment by calcining an intimate mixture of one part of bichromate of potash and three parts of baked gypsum, of the variety known as *scagliola*. The result is a grass-green mass which, on boiling with water, or mixing with dilute hydrochloric acid, leaves a fine powder of an intense green.

REICHARDT recommends the use of the microscope in determining the mineral contents of potable water. On evaporating a few drops on a plate of glass, it is easy to distinguish carbonate and sulphate of lime and of magnesia, chloride of sodium, and nitrate of potash and of soda. C. Bischof further recommends the use of the same instrument for determining the organic substances contained in water.

A SCHEME has been recently devised for supplying London with an inflammable mixture of gases to replace coal. The new gas, "pyrogen," as it is called, is a mixture of nitrogen and carbonic oxide, three-fourths by weight consisting of the latter gas. The combustion temperature of pyrogen is stated to be 2,700° Cent., and for heating-purposes the flame of the burning gas is to be allowed to raise some good radiating substance to incandesence in an ordinary grate.

FELIZET, of Elbeuf, having observed that in epidemics of foot-and-mouth disease no beast affected with cow-pox is ever stricken with the former disorder, vaccinated thirty oxen, and not one of the twenty-five beasts effectually vaccinated showed any sign of foot-and-mouth disease, even after living for months among animals largely affected with it.

PROF. STANLEY JEVONS is opposed to the project of assimilating the American dollar to the English pound sterling; he advocates, rather, assimilation to the five-franc piece. The partial accession of the United States to the franc system would, he says, immensely increase the motives for the English to accept it also, thus preparing the way for an international coinage.

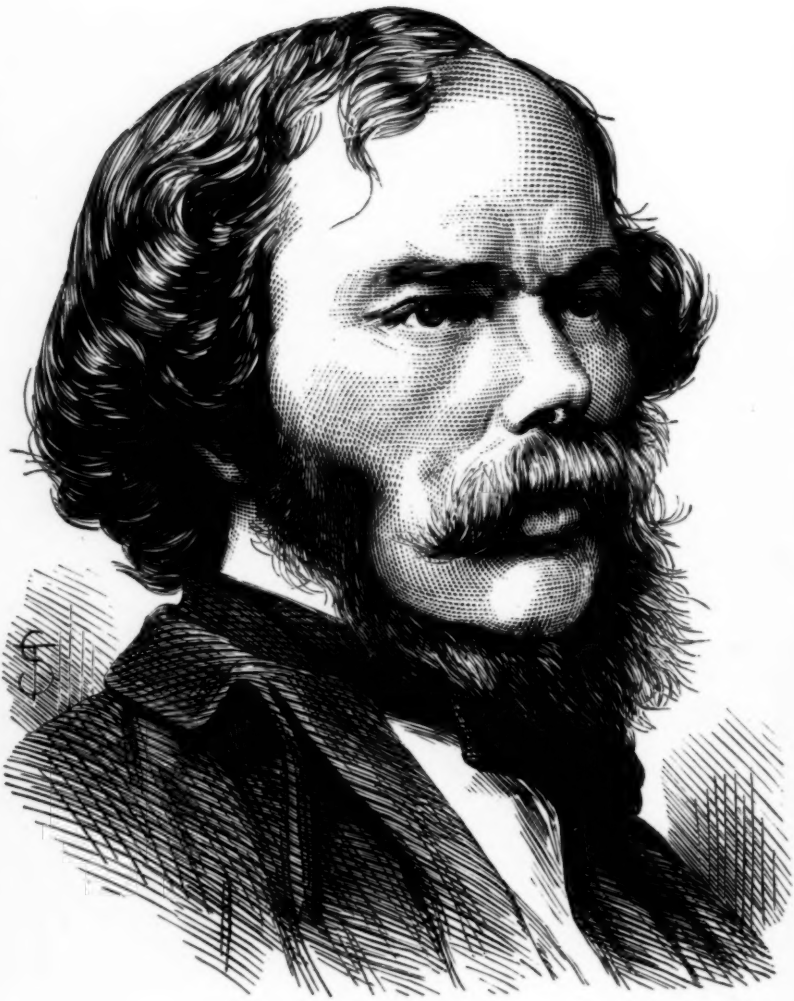
FOR the purpose of photographing solar eclipses, Mr. Brothers, of the Royal Astronomical Society of London, suggests that at least three achromatic lenses of five or six feet focal length, corrected for the actinic rays, should be constructed, with all suitable apparatus, to be in readiness for use when required. The light of the corona, he adds, is sufficiently actinic to produce good pictures when an instrument of long focus is used—it is only a question of time in the exposure and accuracy in the adjustment of the driving-clock apparatus attached to the equatorial mounting.

THE cruelty-to-animals bill, now under consideration in the British Parliament, provides that vivisection should only be performed with a view to the advancement of human knowledge, the prolongation of human life, or the alleviation of human suffering; that it must take place in a registered laboratory; that it must be performed by a person duly licensed; that the animals must be put under the influence of anæsthetics; and that, where pain would be prolonged after the anæsthetic effects had subsided, the animals should be killed.

IN their last report, the Commissioners in Lunacy in England discourage the practice, which has grown to be quite general, of filling up the asylums with idiots, imbeciles, and eccentric or troublesome paupers, to the exclusion of the really insane, who need and are entitled to the skill, care, and attention, that asylums are intended to afford.

THE Commission Supérieure of the Paris Exposition of 1878 has decided upon the general plan of the enterprise, and estimated the probable receipts. The expense is set down at 35,000,000 francs, and the receipts at 19,000,000; difference, 16,000,000 francs. To meet this deficit, the city of Paris will contribute 6,000,000 francs, and the state 10,000,000 francs. The buildings for the exposition will be erected in the Champ de Mars and in the Trocadero—localities situated on opposite banks of the river Seine. At first, it was proposed to widen temporarily the bridge known as Pont d'Iéna, but soon another project was entertained—that of erecting a new bridge forty metres in width. The question is yet under deliberation.

IN the petroleum-mines of Alsace the miners test their safety-lamps in the following manner before going down the pits: At the bottom of an open jar is placed a small quantity of petroleum-spirit, the vapor of which, mingling with the air in the jar, forms an explosive mixture. The lamp is plunged into this mixture, and the slightest defect in the lamp is proved by an explosion.



GEORGE HENRY LEWES.